Transition of the Combined Radar-Radiometer Algorithm from V04 to V05

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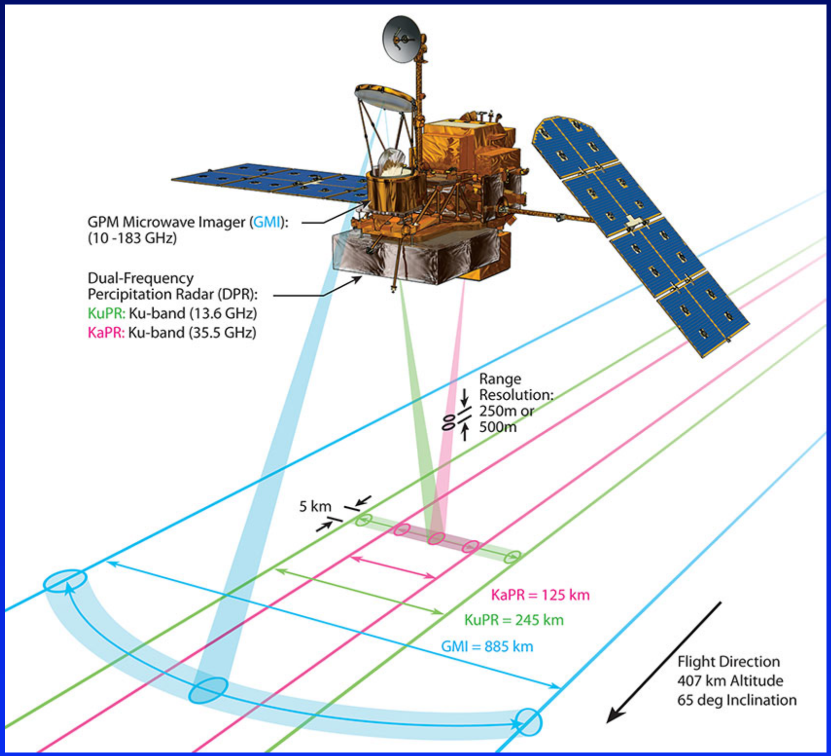
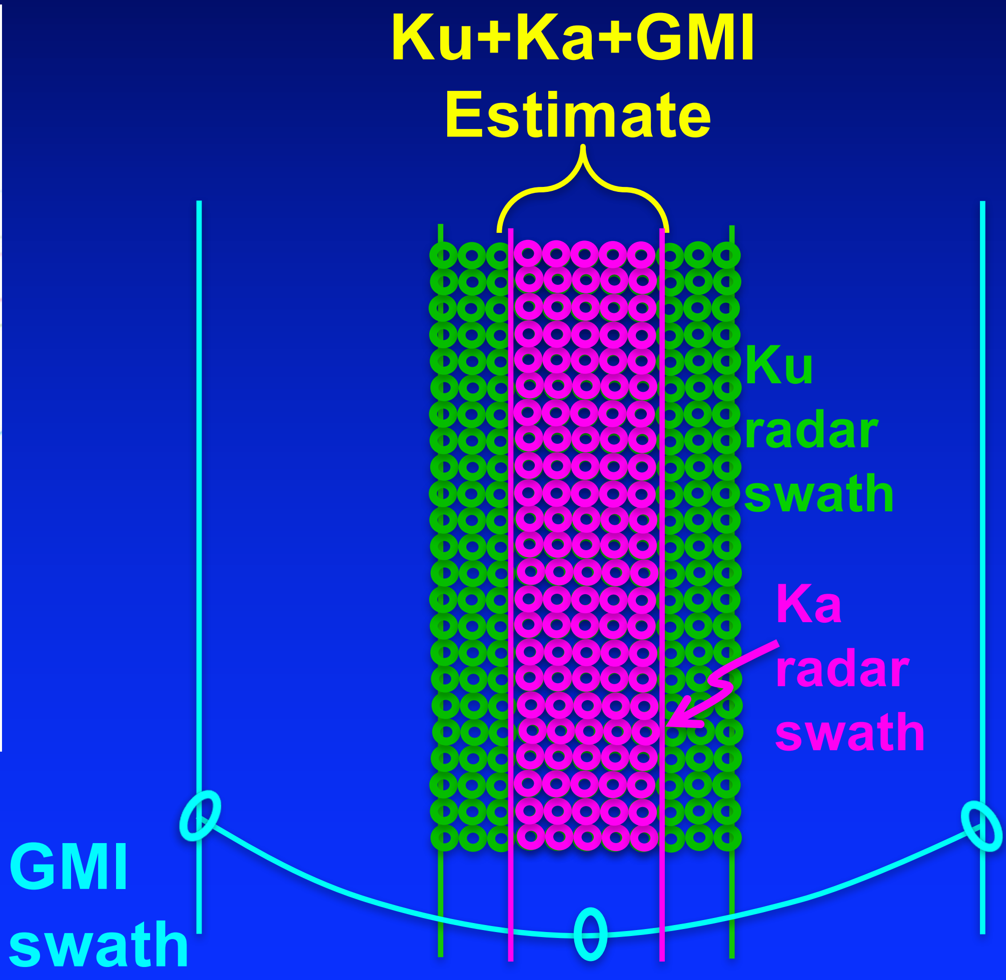
with support from

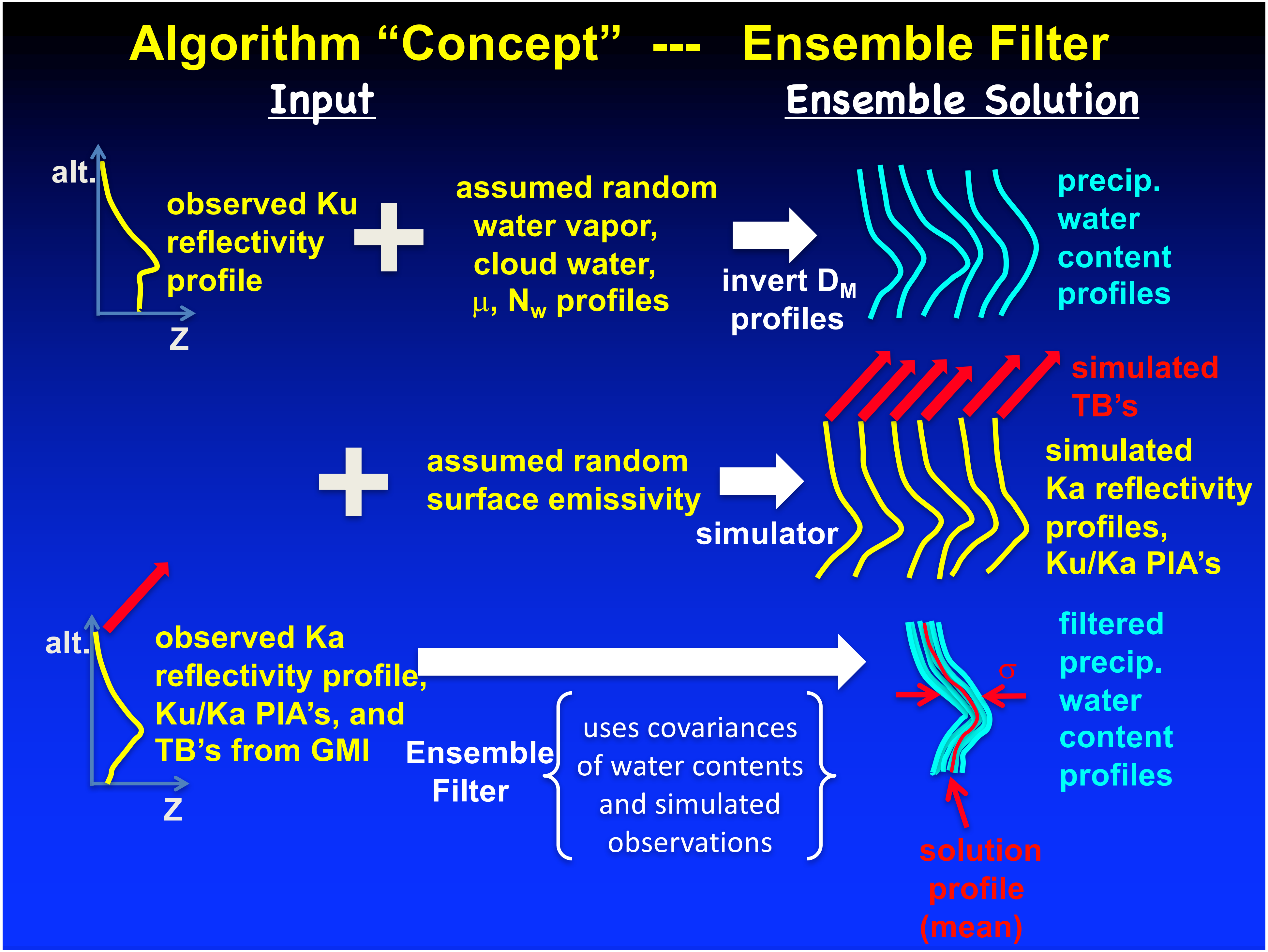
the Radar and Radiometer Algorithm Teams, the GV Team,
WG's, and Precipitation Processing System Personnel

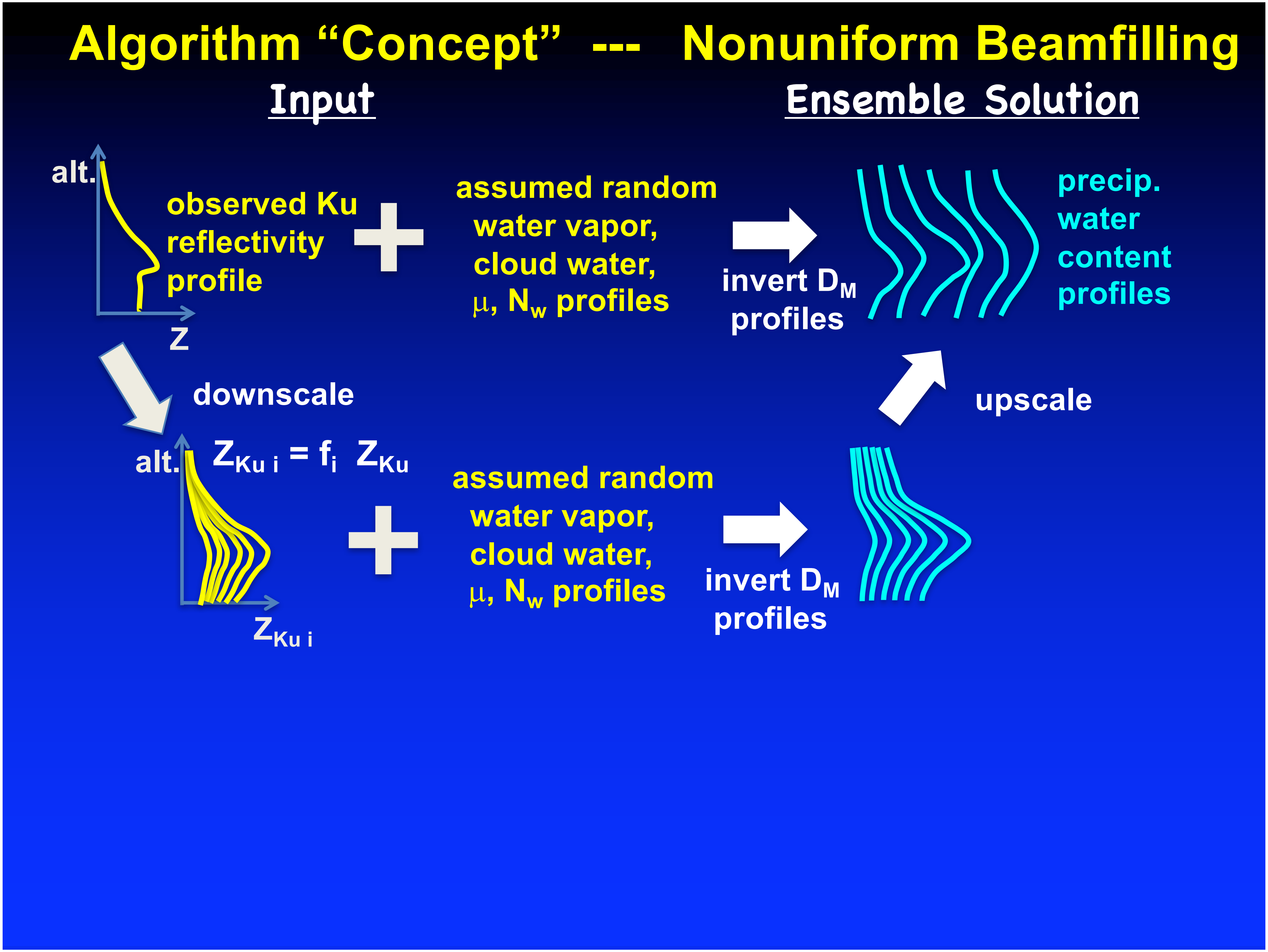
Combined Radar-Radiometer Algorithm Input

- Dual-Frequency Precipitation Radar (DPR); Ku & Ka bands
- GPM Microwave Imager (GMI); 10 – 183 GHz.






Algorithm "Concept" --- Ensemble Filter
Input
Ensemble Solution
alt.
Z
observed Ku reflectivity profile
assumed random water vapor, cloud water, μ, N_w profiles
invert D_M profiles
precip. water content profiles
simulated TB's
assumed random surface emissivity
simulator
simulated Ka reflectivity profiles, Ku/Ka PIA's
alt.
Z
observed Ka reflectivity profile, Ku/Ka PIA's, and TB's from GMI
Ensemble Filter
uses covariances of water contents and simulated observations
σ
filtered precip. water content profiles
solution profile (mean)


Algorithm "Concept" --- Nonuniform Beamfilling
Input
Ensemble Solution
alt.
Z
observed Ku reflectivity profile
assumed random water vapor, cloud water, μ, Nw profiles
invert DM profiles
precip. water content profiles
downscale
upscale
alt.
ZKu i = fi ZKu
ZKu i
assumed random water vapor, cloud water, μ, Nw profiles
invert DM profiles

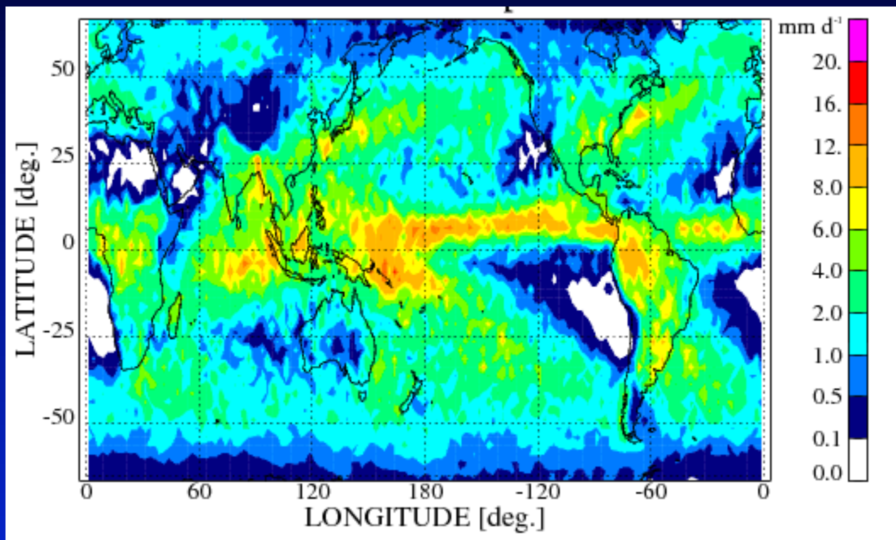
What we added with V04:

- GMI radiances were resolution-enhanced using regression-based filters; using all GMI channels.
- Hogan & Battaglia model for multiple-scattering in radar simulations was utilized where needed.

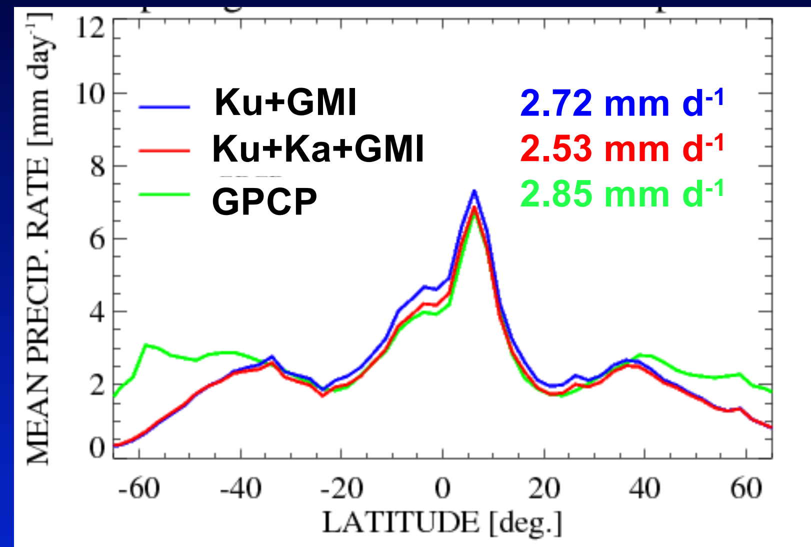
(note: V04 described in Grecu et al. 2016 *JAOT* article)

Comparison of GPM Mean Precip. vs. GPCP and MRMS Sep. – Aug. 2014/2015 *Dave Bolvin*

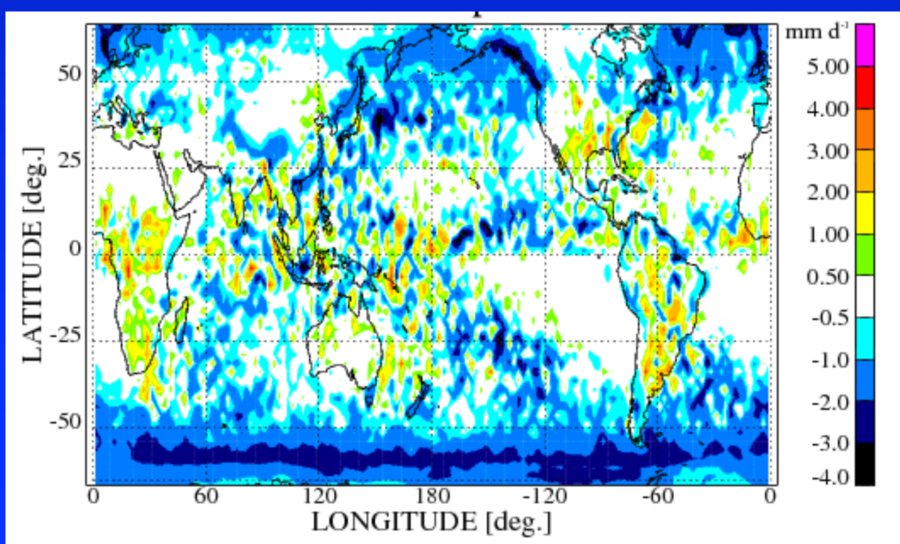
Combined V4 Ku+Ka+GMI



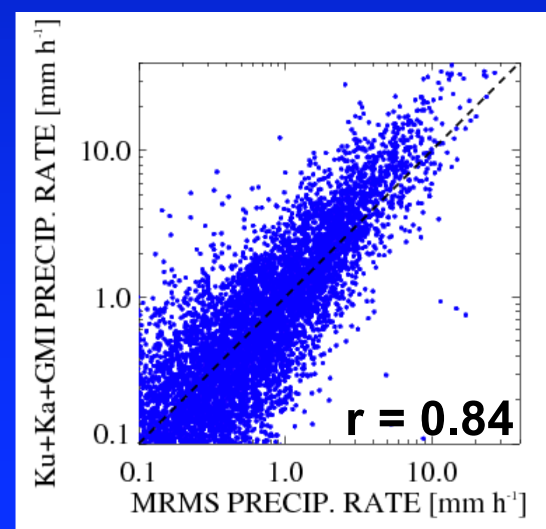
Combined V4 and GPCP



V4 - GPCP



Combined V4 vs MRMS



Combined Algorithm V5 Updates and TRMM V8

- Changed initial assumptions on PSD's and ensemble generation.

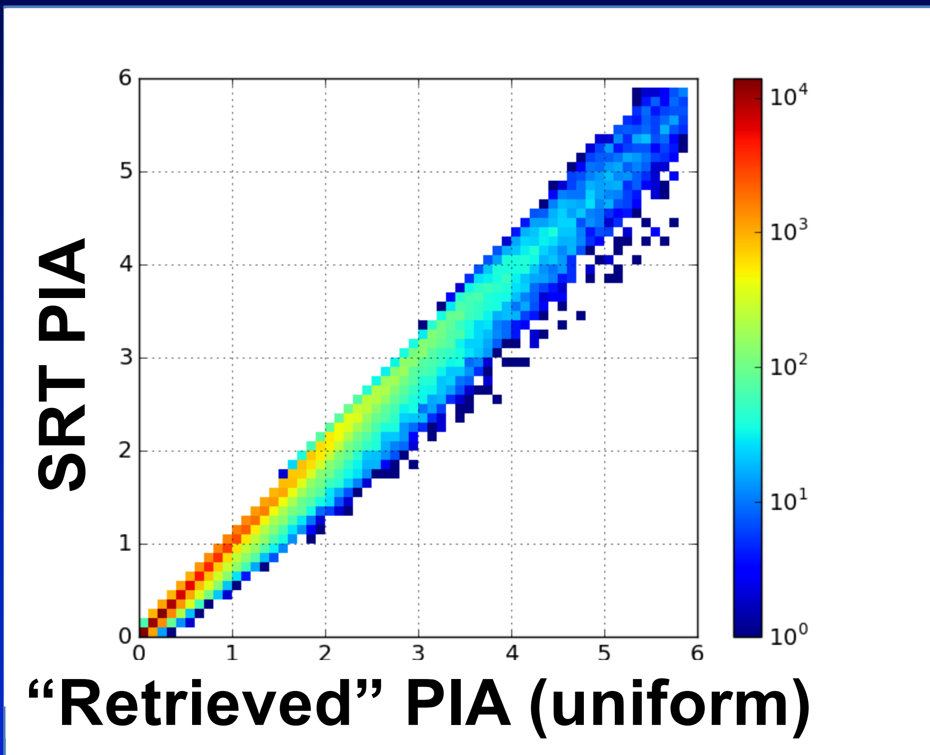
★ Revised modeling of path-integrated attenuation in response to non-uniform beamfilling effects.

In process:

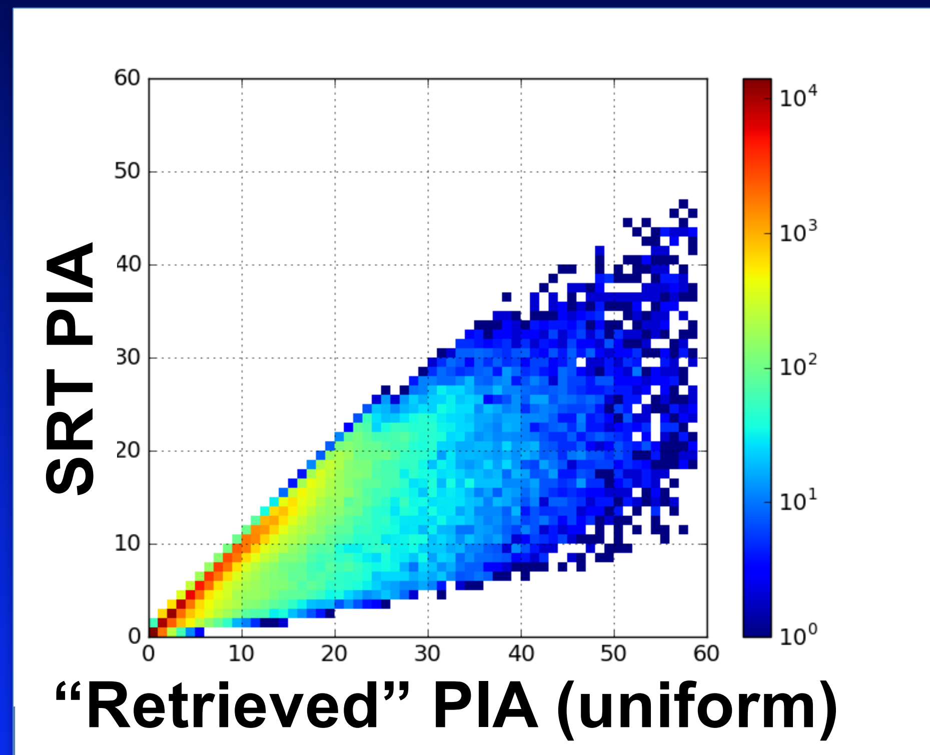
- Nonspherical ice particle scattering tables.
- σ^0 – emissivity surface parameterization.
- Have begun interfacing Combined with TRMM input.

Radar-Based Simulations of Beamfilling-Affected Path Integrated Attenuation *Mircea Grecu*

PIA at Ku Band



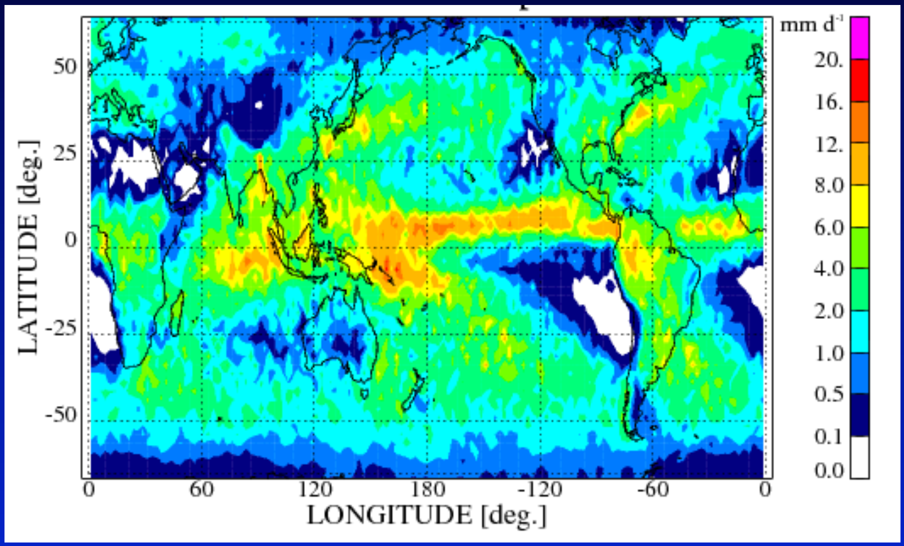
PIA at Ka Band



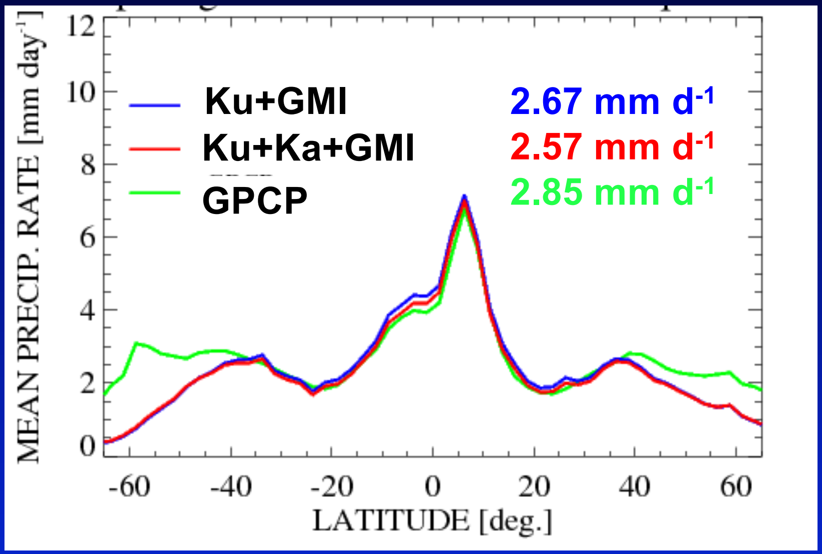
- Use high-resolution ground radar to simulate SRT PIA and attenuated reflectivities over DPR footprint.
- Retrieve PIA's, assuming uniform beamfilling.

Comparison of GPM Mean Precip. vs. GPCP and MRMS Sep. – Aug. 2014/2015 *Dave Bolvin*

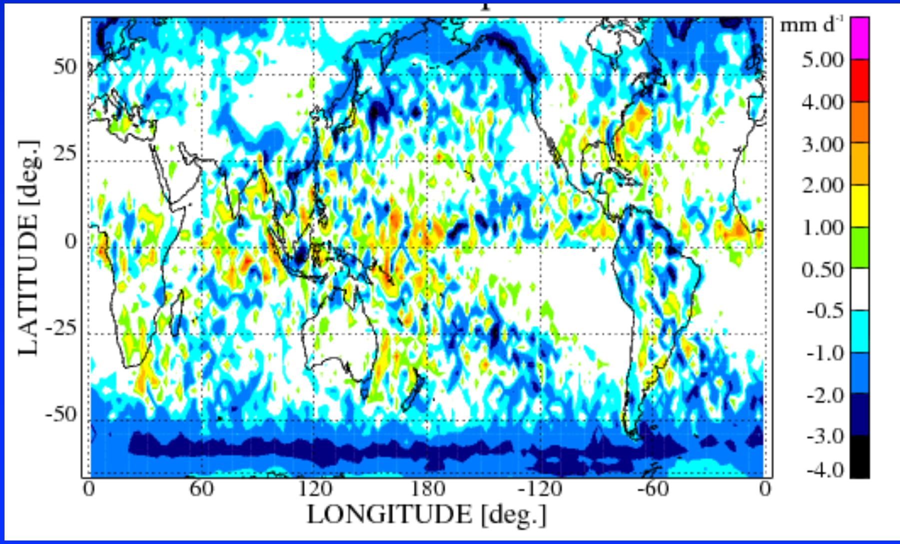
Combined ITE Ku+Ka+GMI



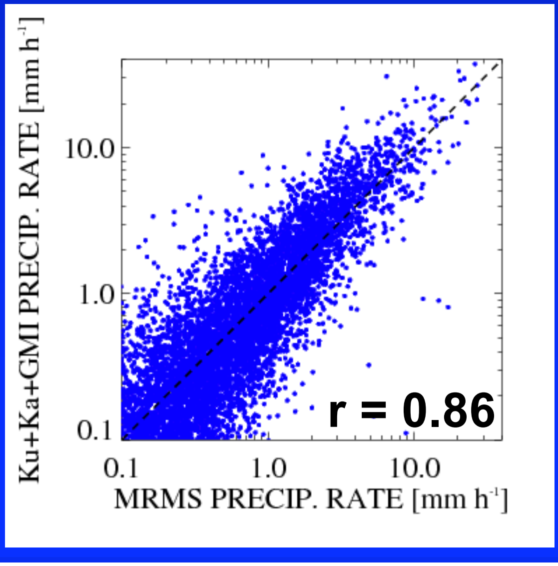
Combined ITE and GPCP



ITE - GPCP

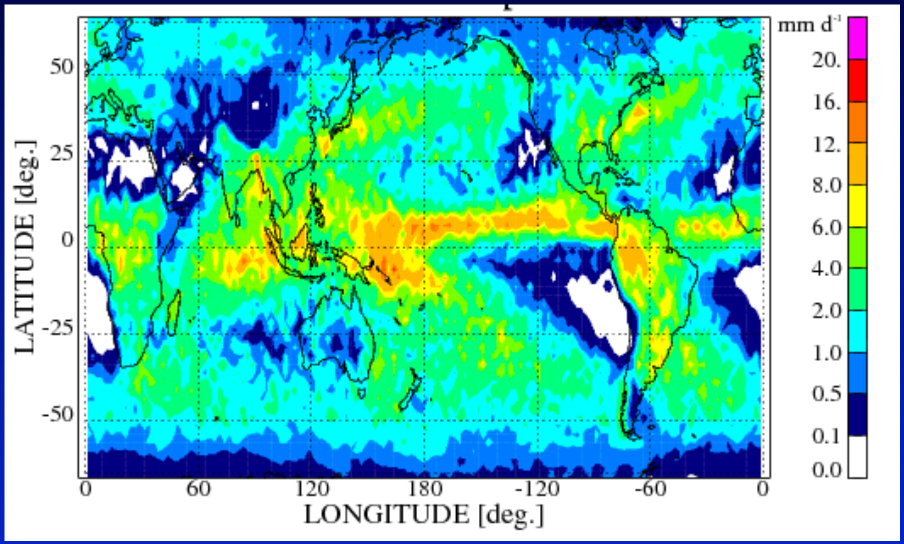


Combined ITE vs MRMS

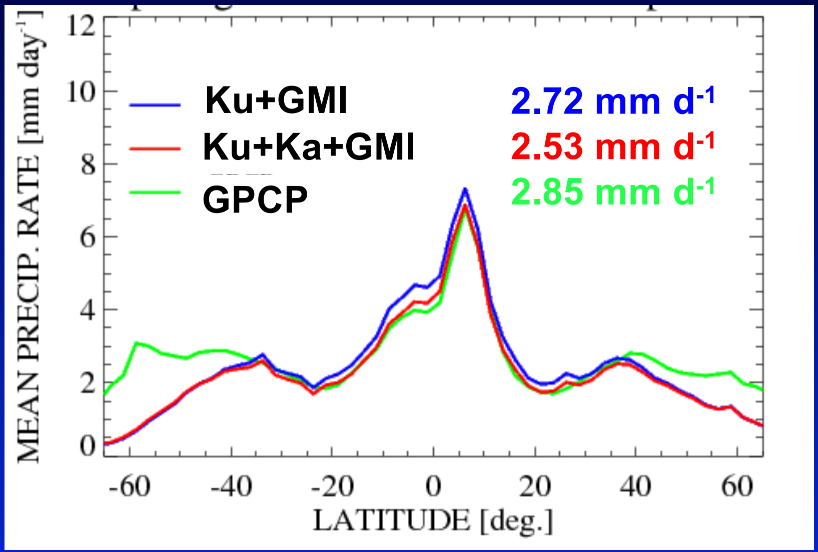


Comparison of GPM Mean Precip. vs. GPCP and MRMS Sep. – Aug. 2014/2015 *Dave Bolvin*

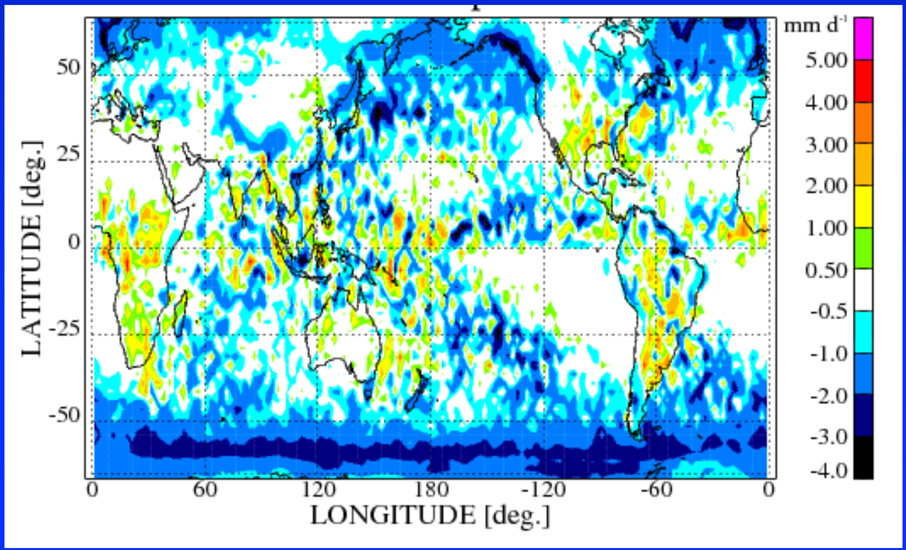
Combined V4 Ku+Ka+GMI



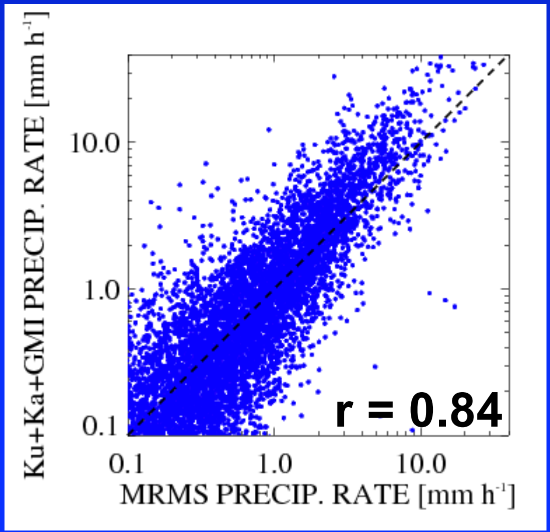
Combined V4 and GPCP



V4 - GPCP

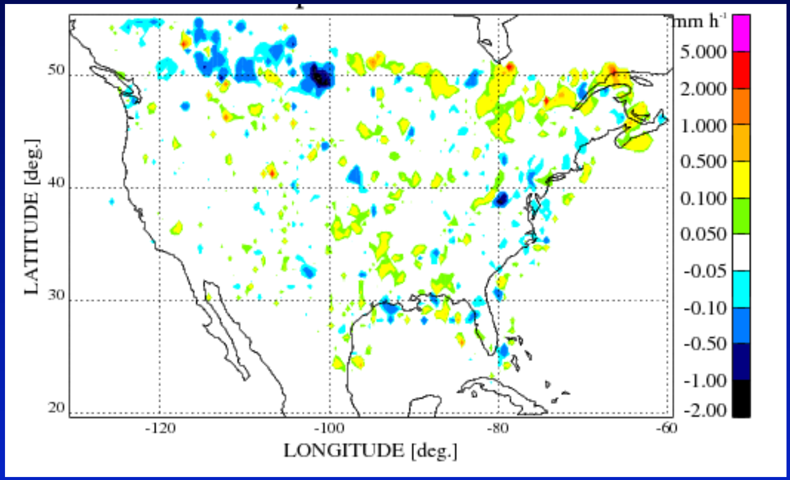


Combined V4 vs MRMS

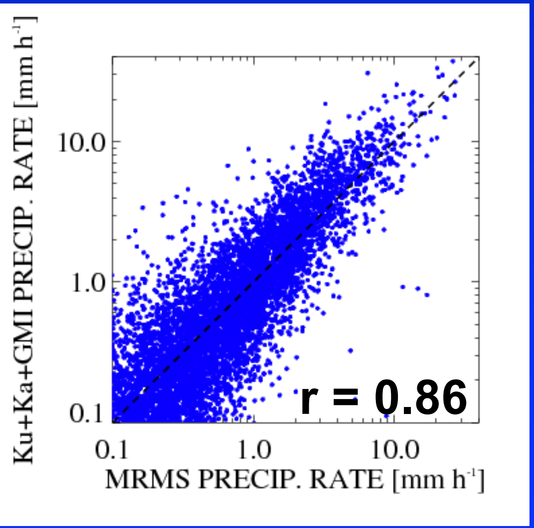


Comparison of ITE vs. MRMS
Sep. - Aug. 2014/2015

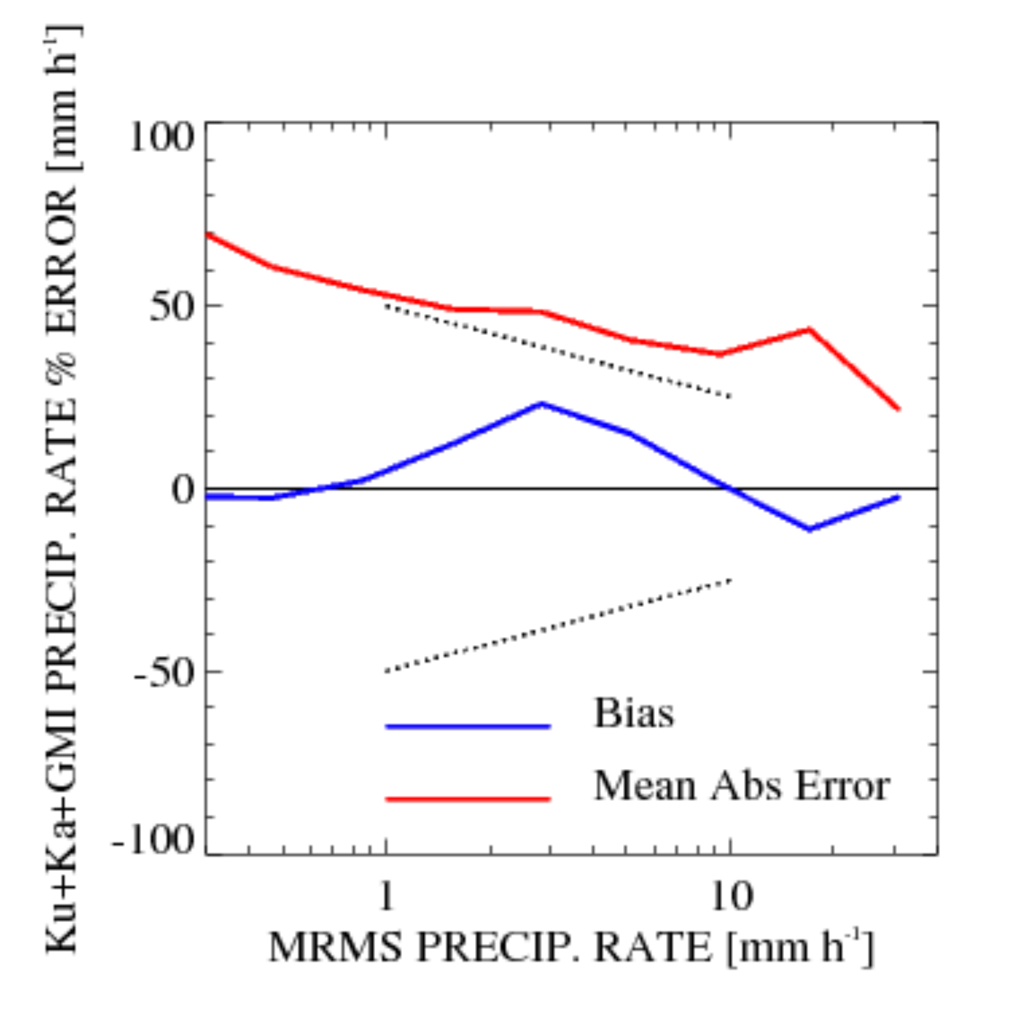
Combined ITE – MRMS



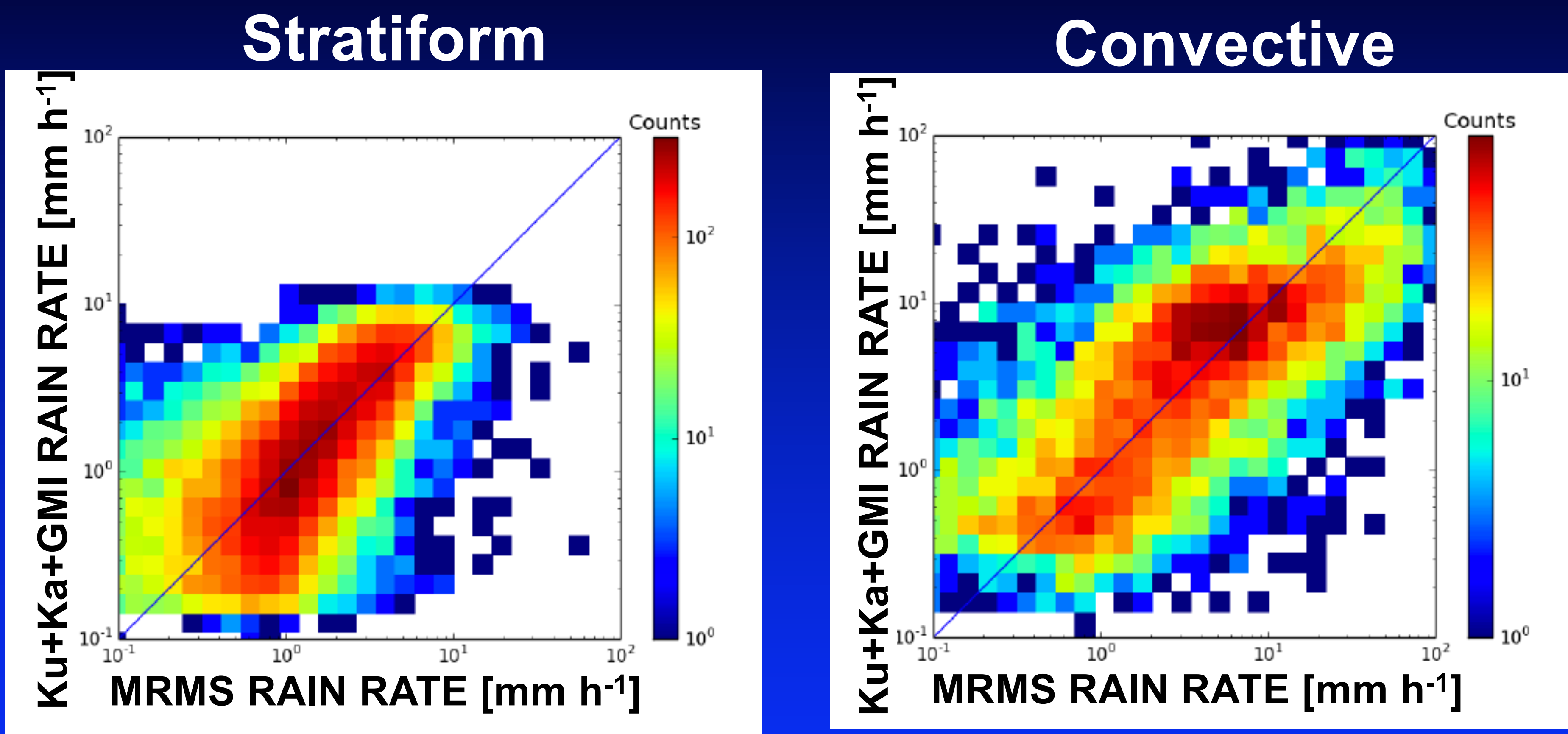
Combined ITE vs. MRMS



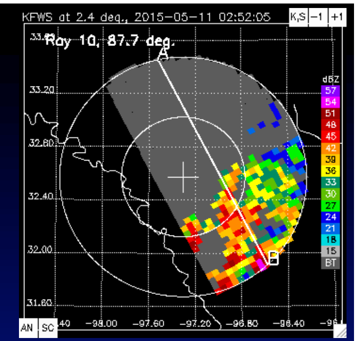
Combined ITE Errors vs. MRMS



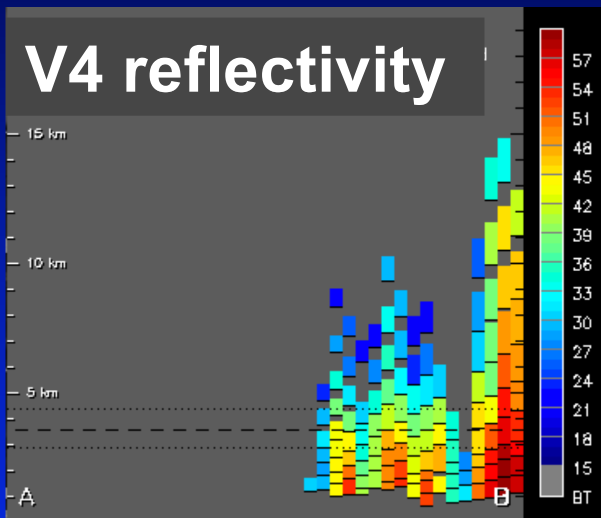
Comparison of ITE Ku+Ka+GMI and MRMS Rain Rates at Footprint Resolution

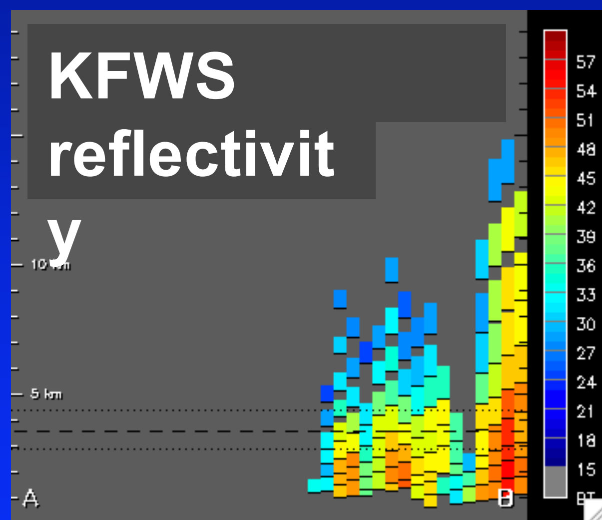


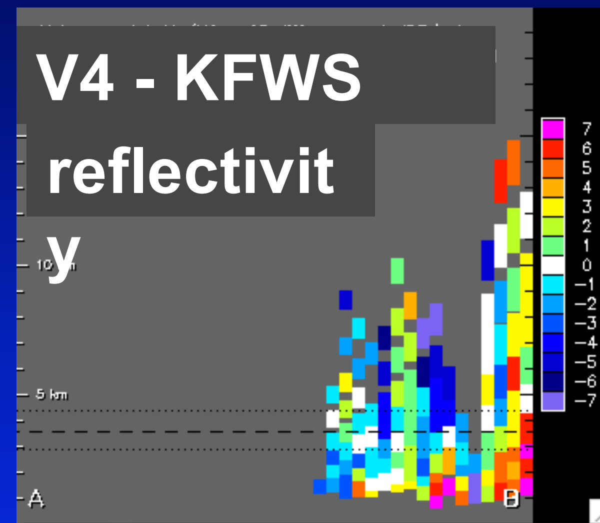
Comparison of GPM V4 vs. ITE Corrected Ku Reflectivity on May 11, 2015 Using "Validation Network" Matched Data

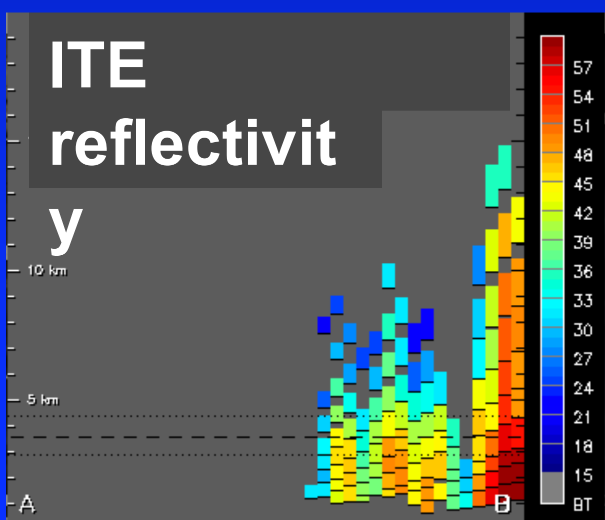


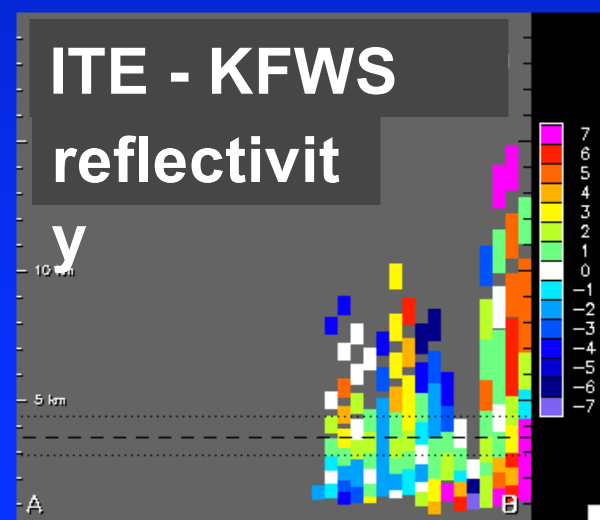
Bob Morris











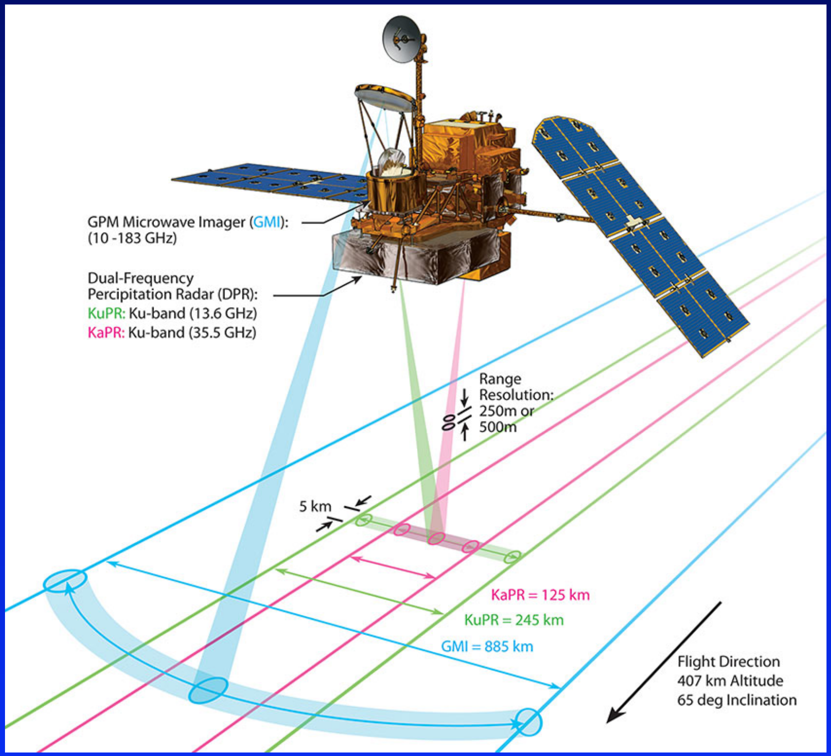
Final Remarks:

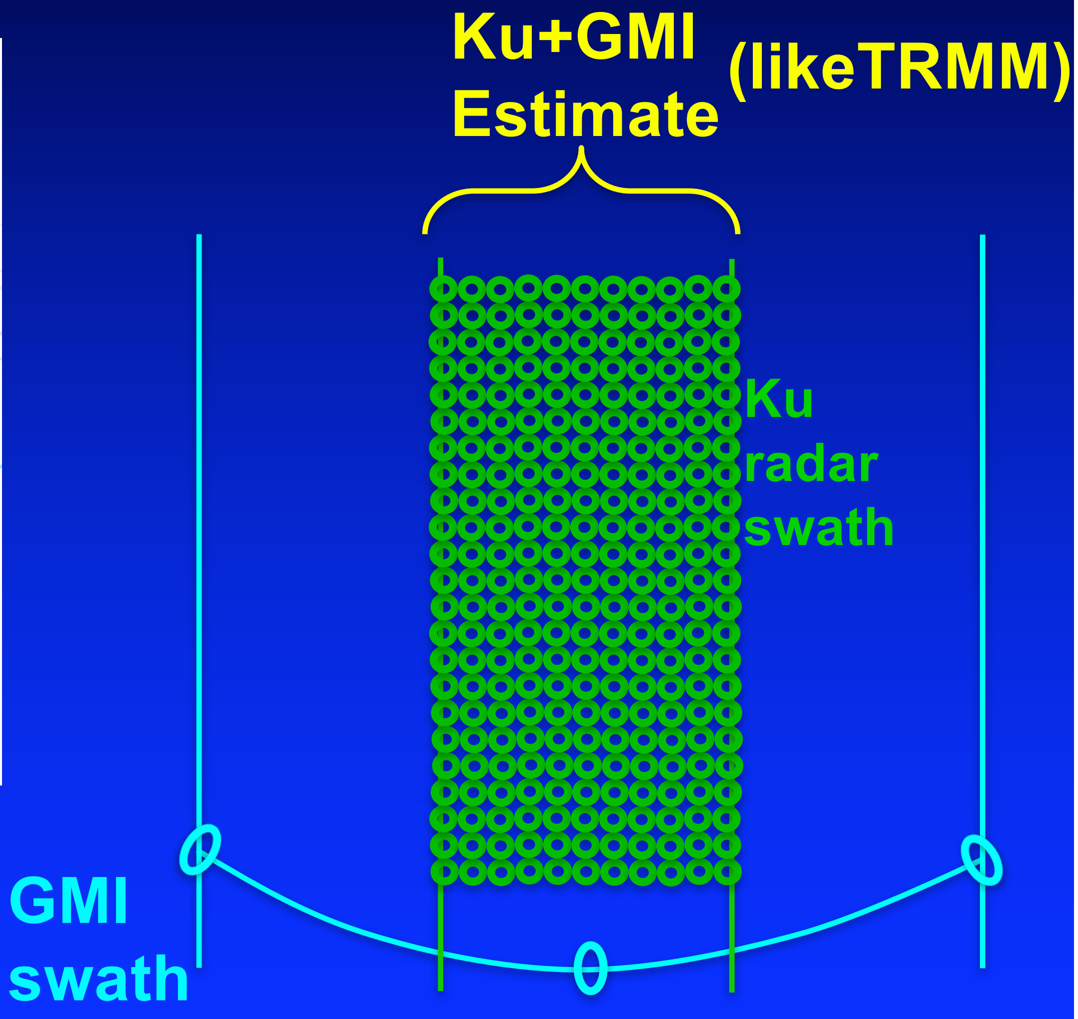
- Combined Algorithm V5 should be ready for delivery 1 month after final Radar Algorithm is delivered.
- In short term, examine relationships between PSD/non-uniform beamfilling assumptions and attenuation correction.
- Non-uniform beamfilling, multiple scattering, ice/mixed-phase particle properties are currently parameterized, but comprehensive descriptions will require longer-term efforts.
- Will work with radiometer team on high latitude estimates. Generate databases for algorithm.

extras

Combined Radar-Radiometer Algorithm Input

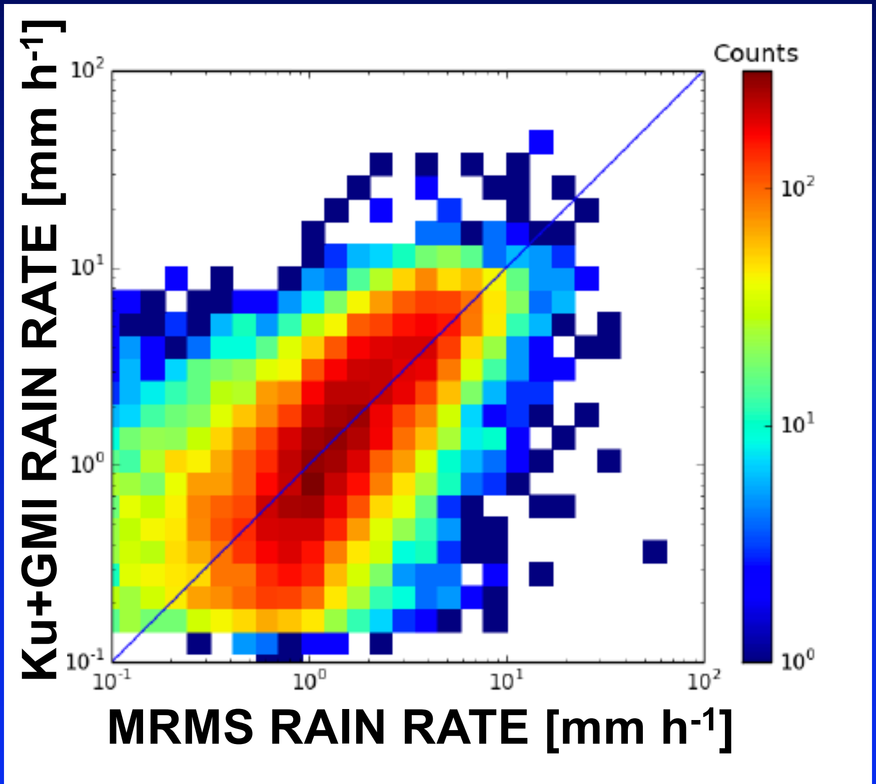
- Dual-Frequency Precipitation Radar (DPR); Ku & Ka bands
- GPM Microwave Imager (GMI); 10 – 183 GHz.



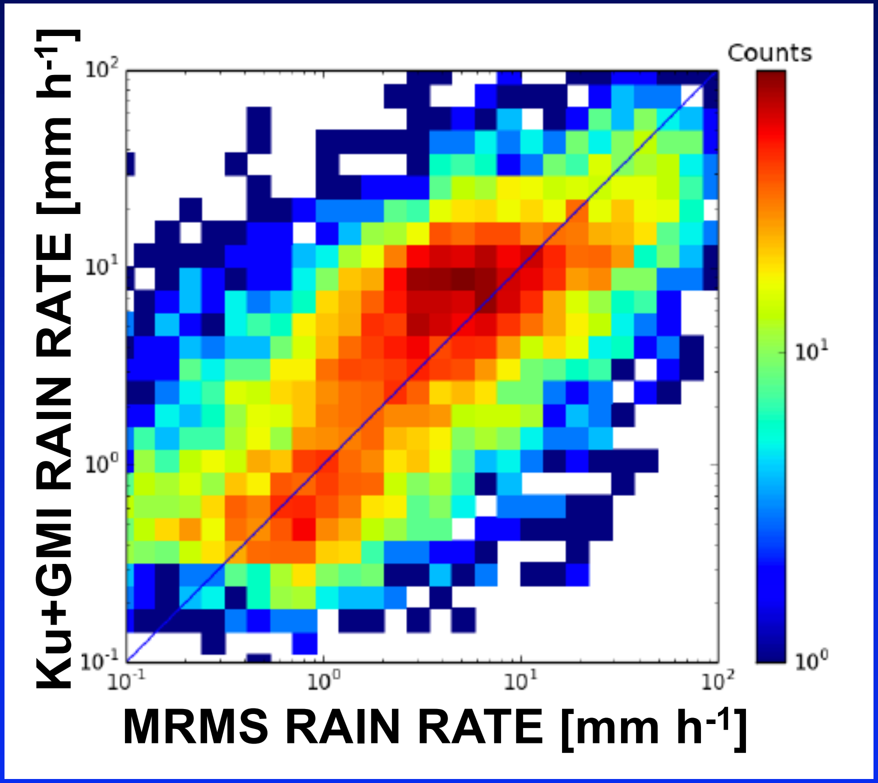


Comparison of ITE Ku+GMI and MRMS Rain Rate at Footprint Resolution

Stratiform

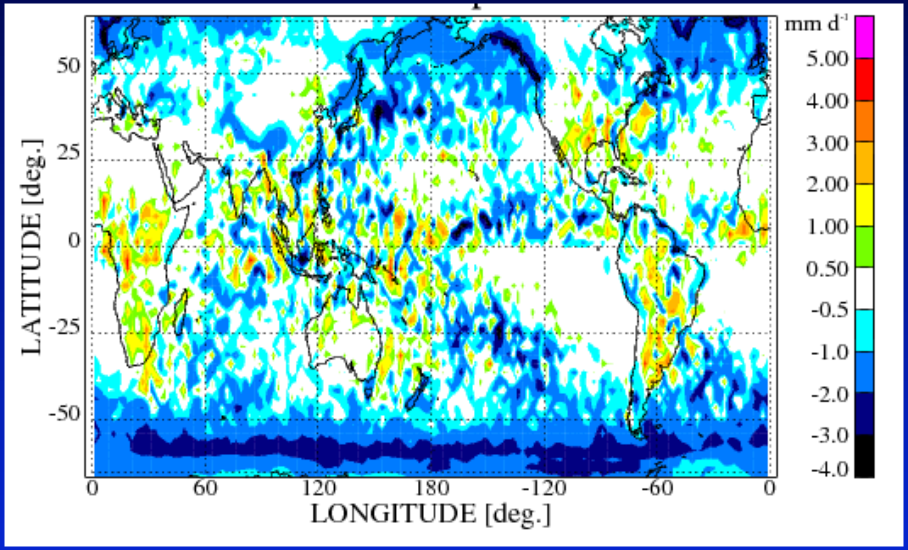


Convective

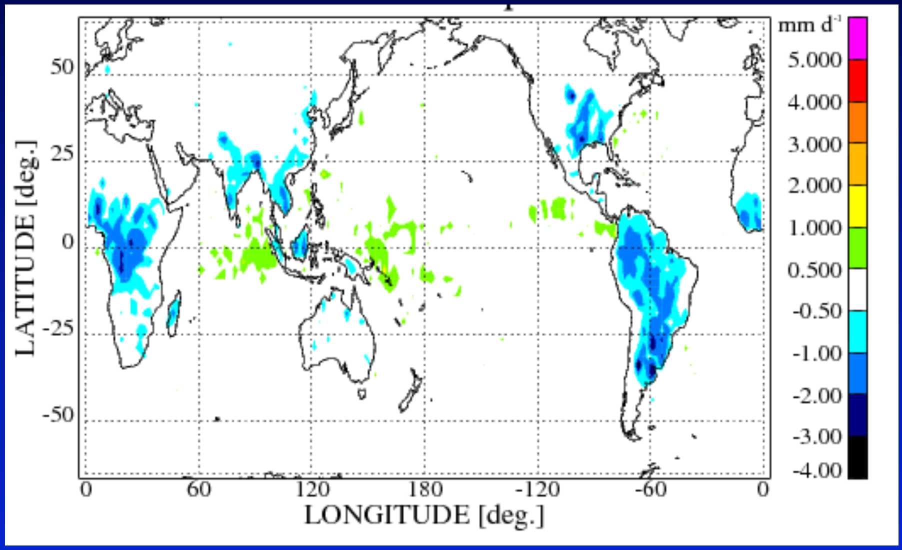


Comparison of GPM V4 vs. ITE
Sep. - Aug. 2014/2015

Combined V4 - GPCP



Combined ITE - V4



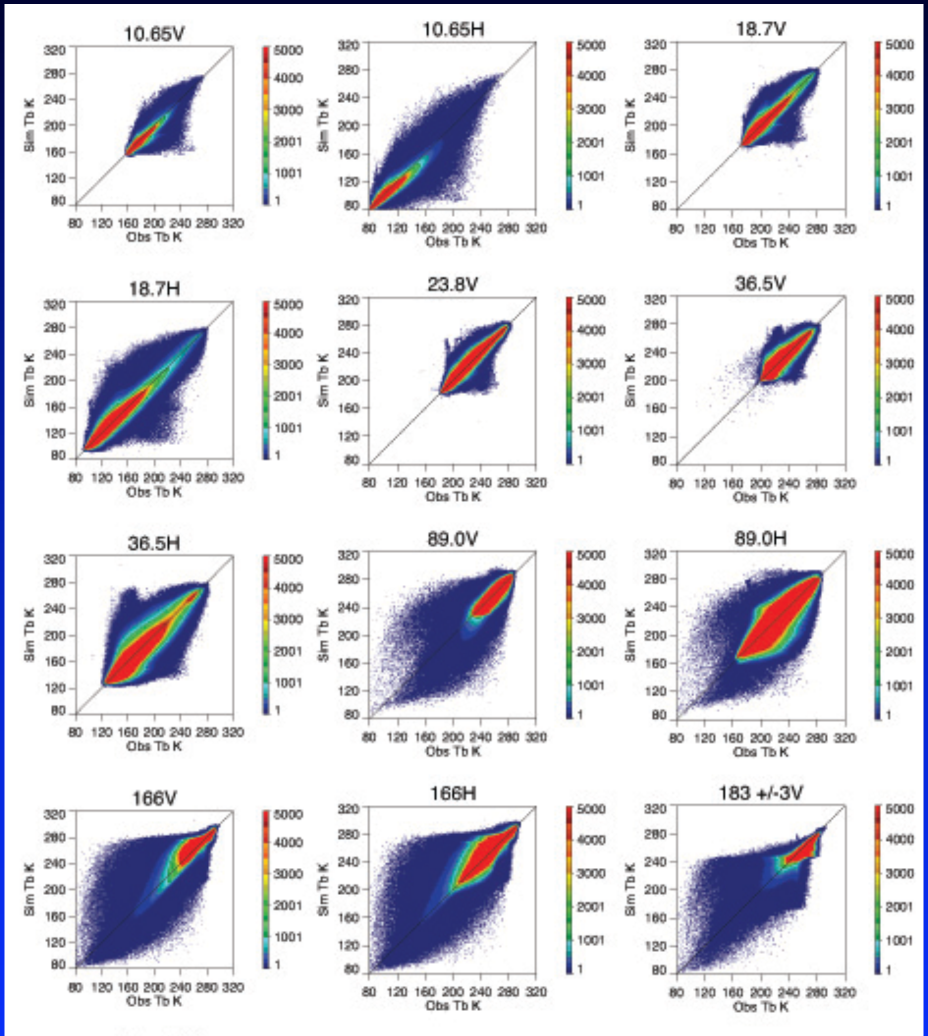
Radiometer Database Generation

- brightness temperatures are simulated using 1 year of retrieved profiles from V4 combined algorithm code.

- ice column is adjusted to get better agreement with high-frequency GMI channels (uses DDA ice).

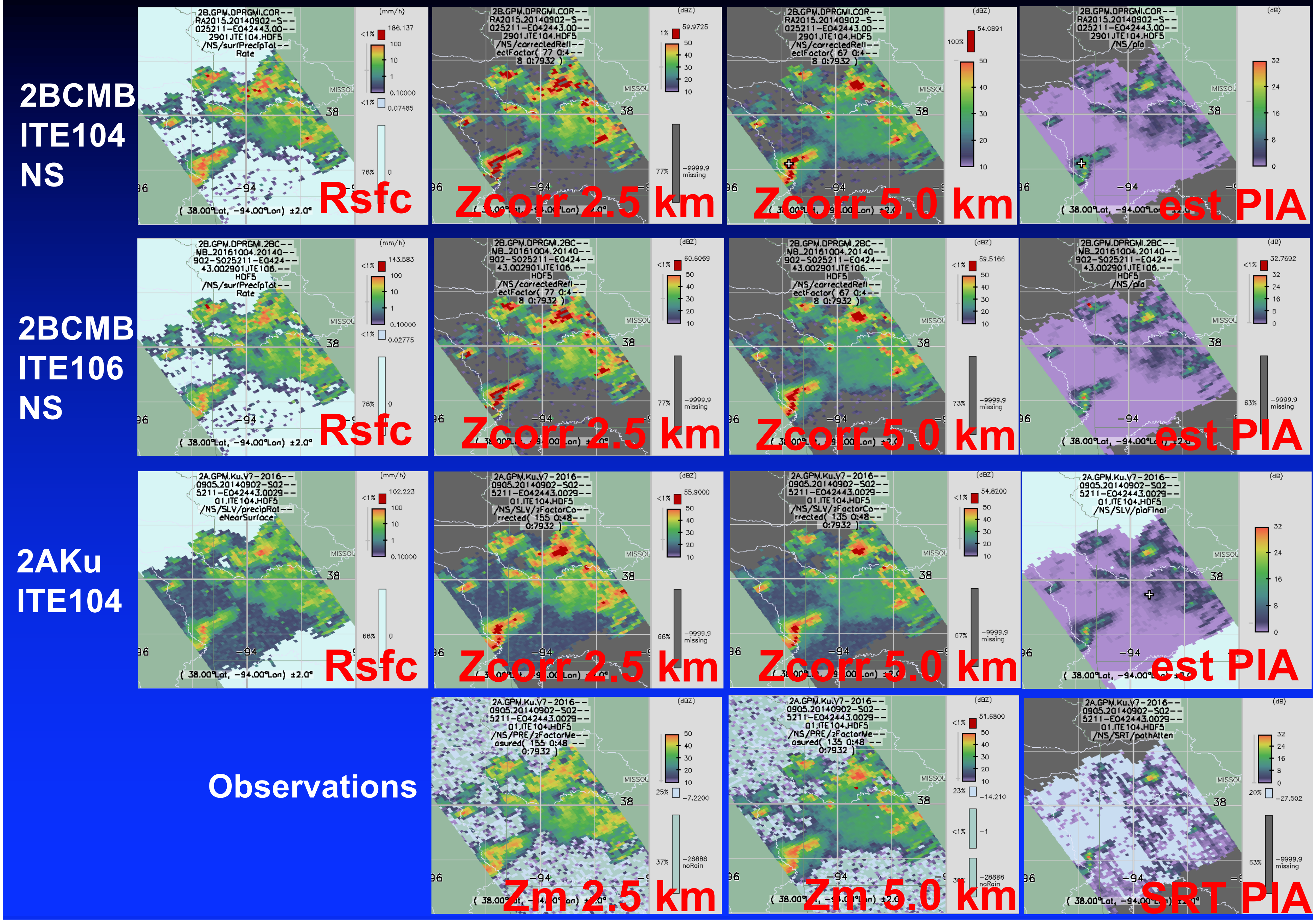
- over ocean comparisons at right.

Simulated vs. Observed TB's



Sarah Ringerud

N_w Study

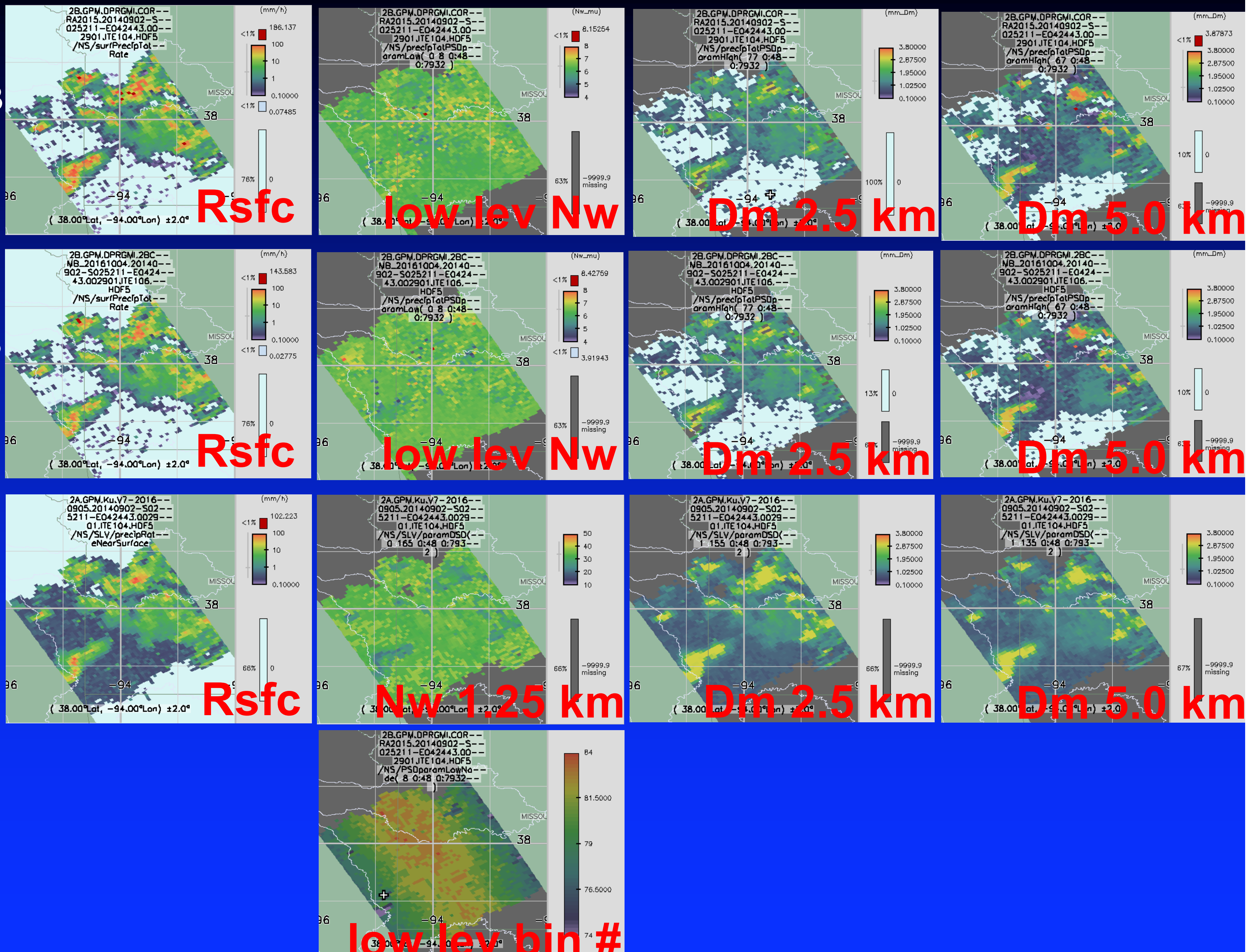

2BCMB
ITE104
NS
Rsfc
Zcorr 2.5 km
Zcorr 5.0 km
est PIA
2BCMB
ITE106
NS
Rsfc
Zcorr 2.5 km
Zcorr 5.0 km
est PIA
2AKu
ITE104
Rsfc
Zcorr 2.5 km
Zcorr 5.0 km
est PIA
Observations
Zm 2.5 km
Zm 5.0 km
SRT PIA

N_w Study

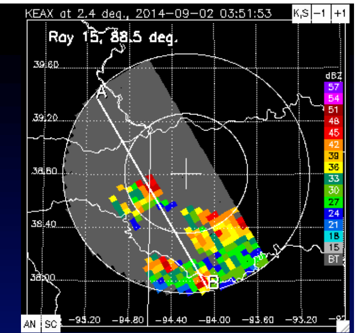
2BCMB
ITE104
NS

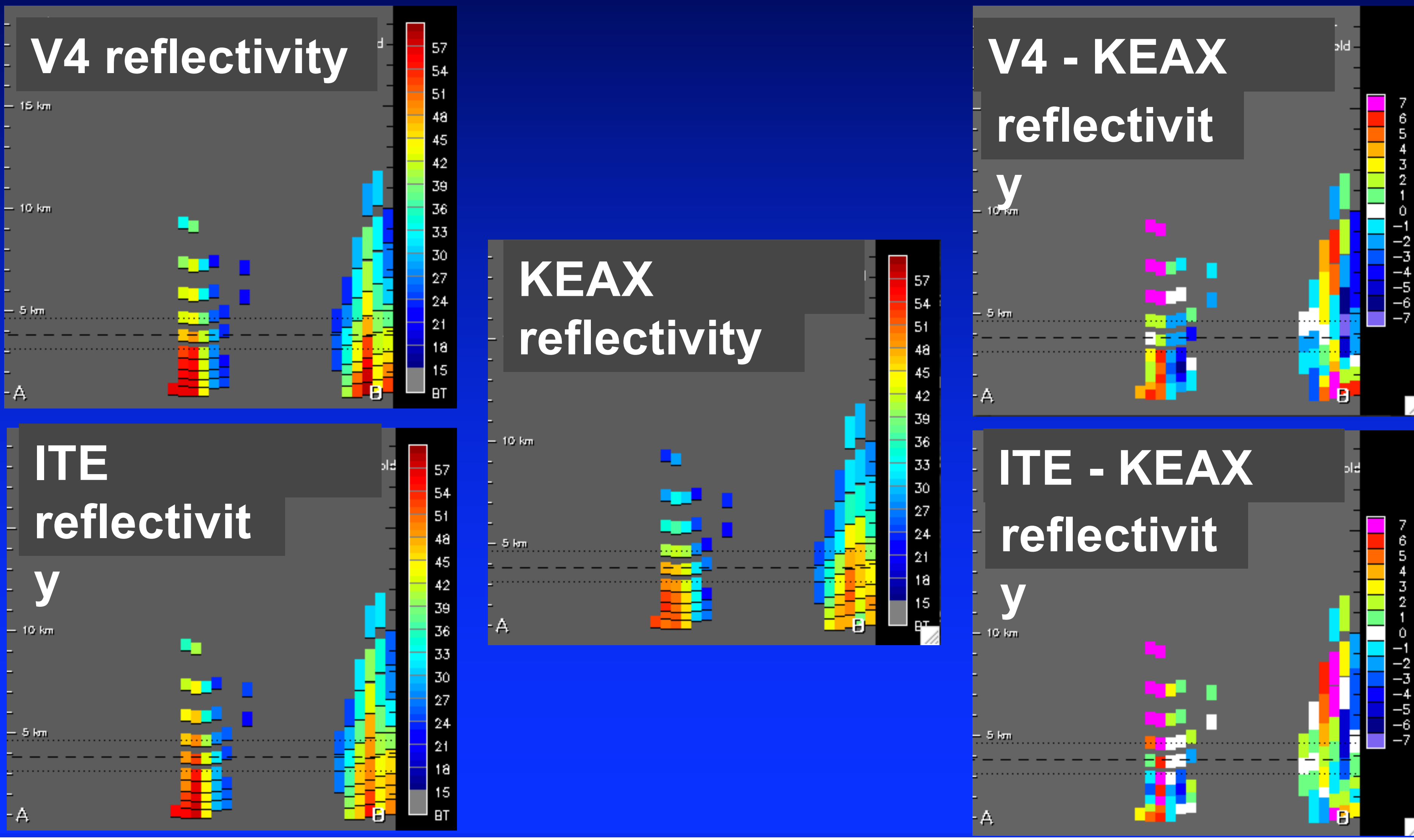
2BCMB
ITE106
NS

2AKu
ITE104



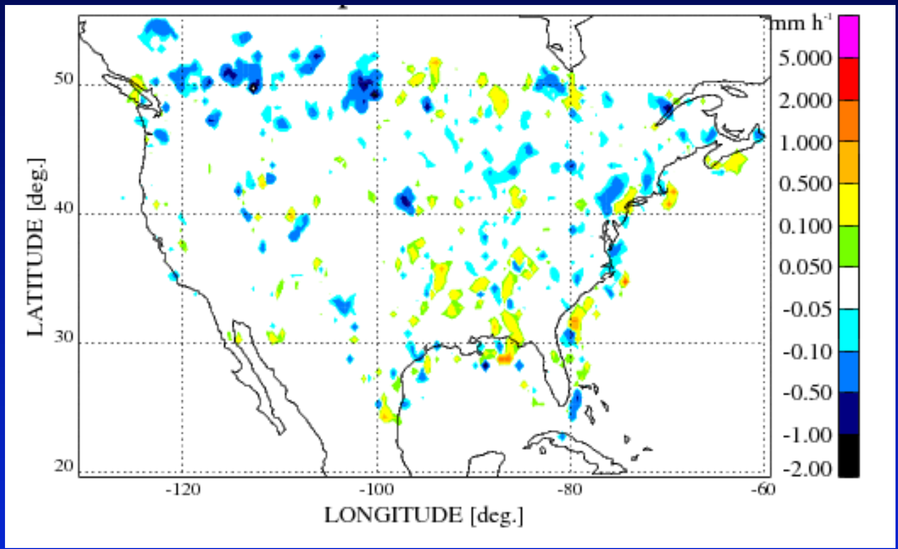
Comparison of GPM V4 vs. ITE Corrected Ku Reflectivity on Sep. 2, 2014 Using VN Matched Data



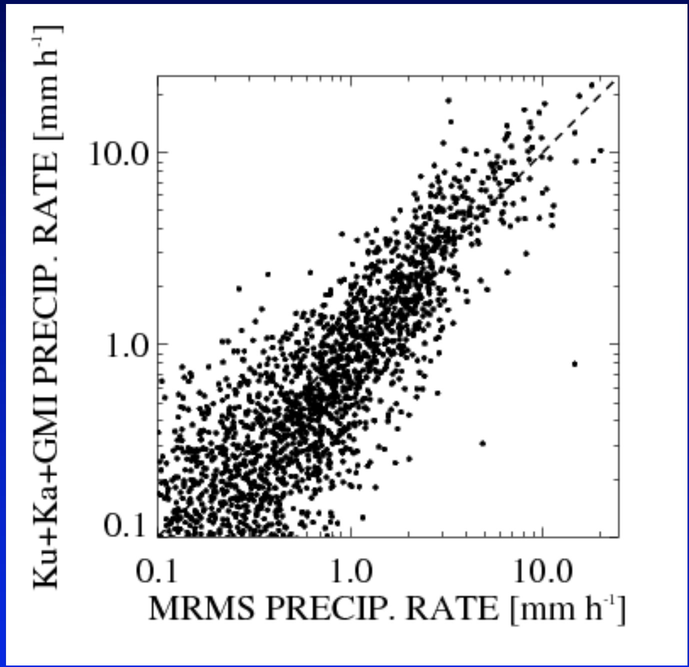


Comparison of GPM and MRMS Radar (Q3) Sep. - Feb. 2014/2015

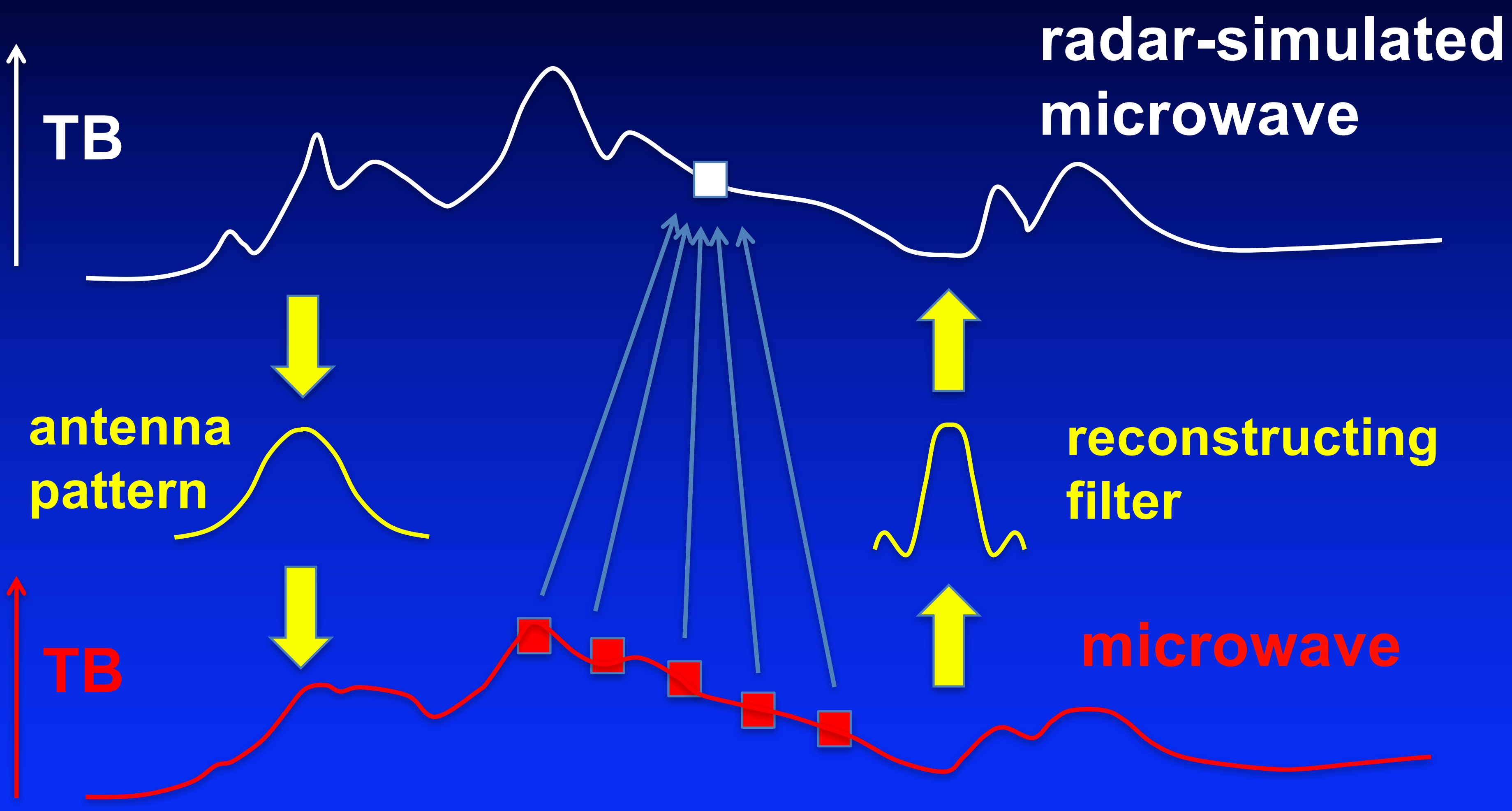
Combined ITE – MRMS



Combined ITE vs. MRMS

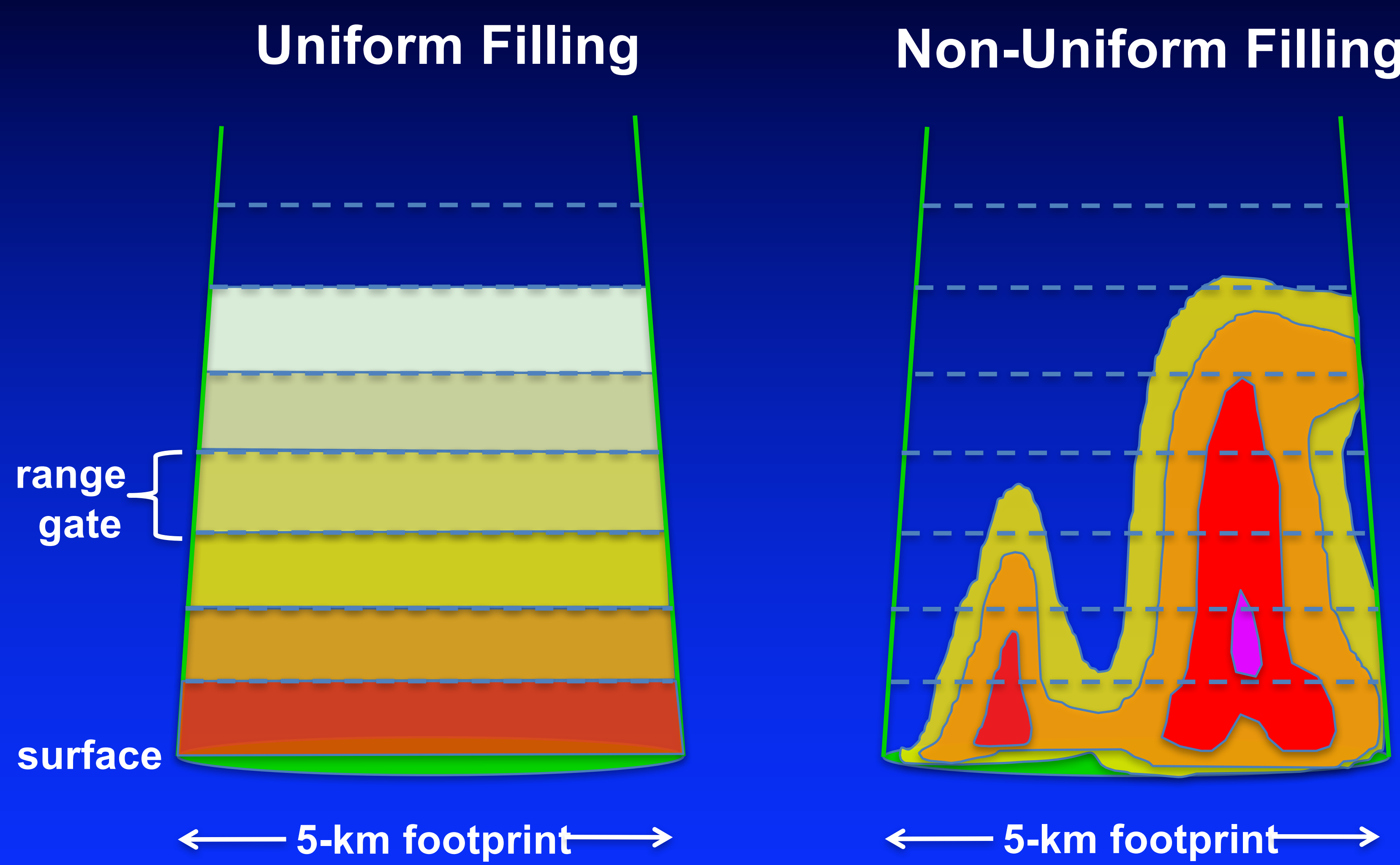


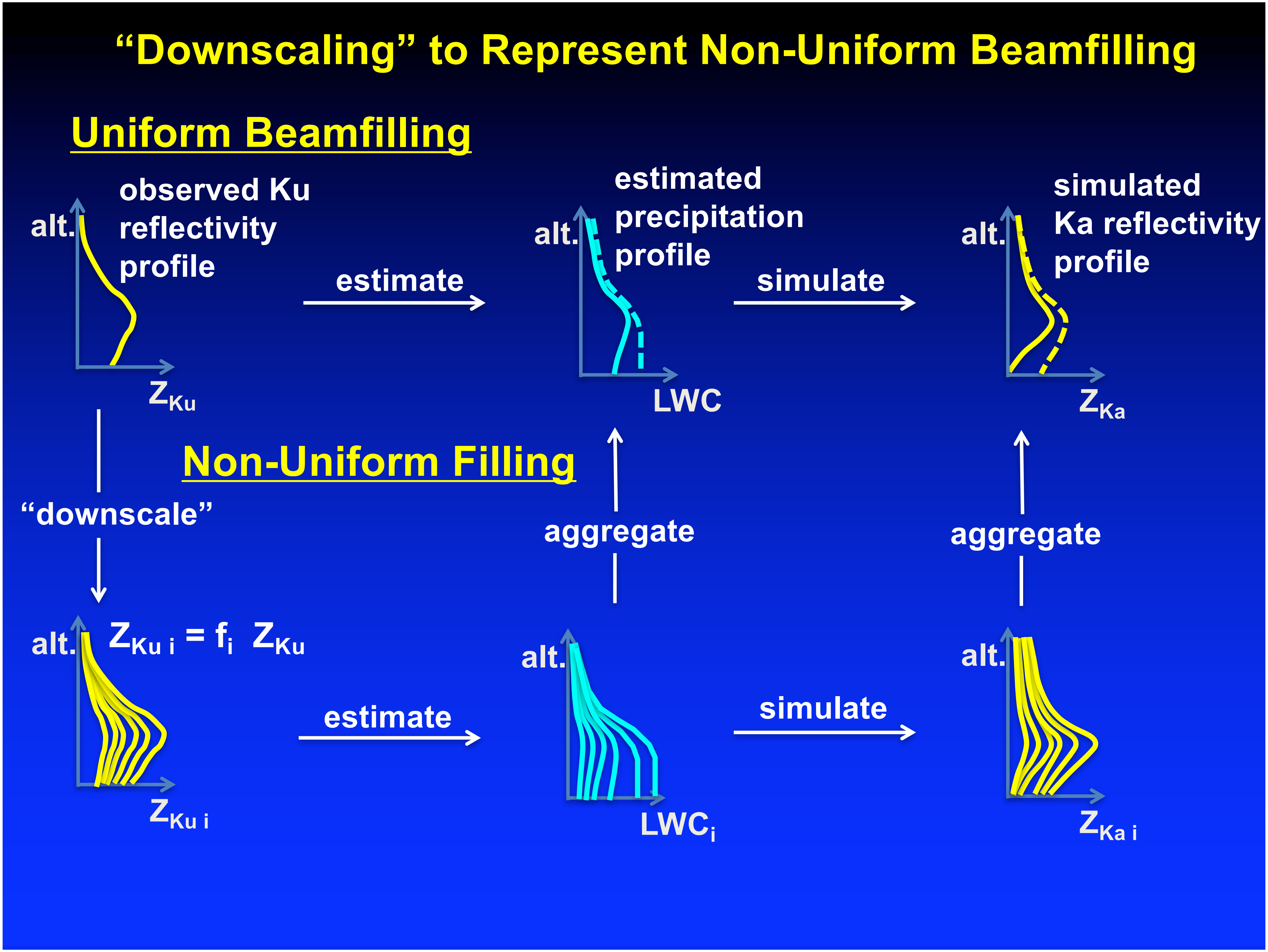
Resolution-Enhancement of GMI Radiances



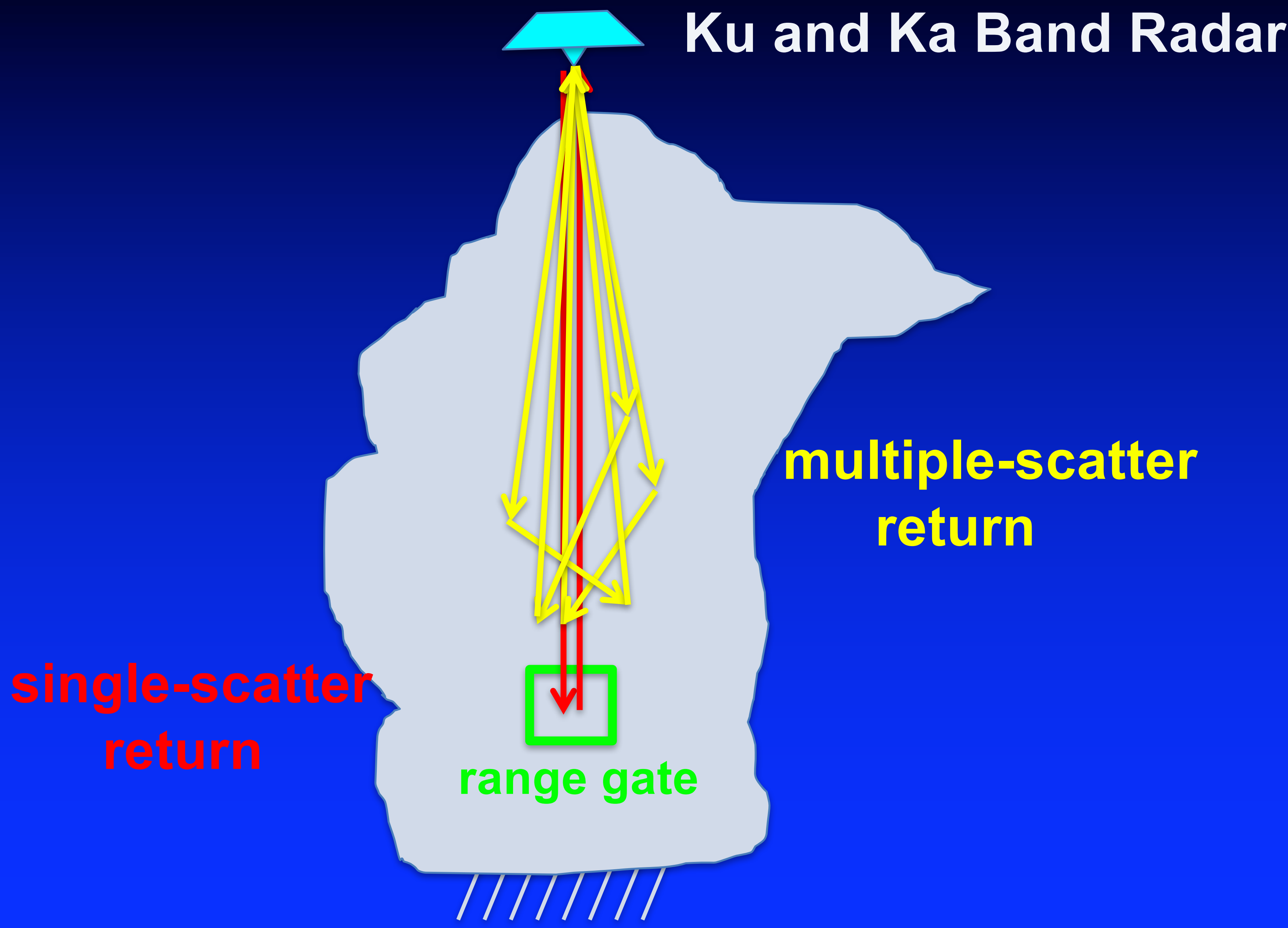
Mircea Grecu

Non-Uniform Precipitation Beamfilling

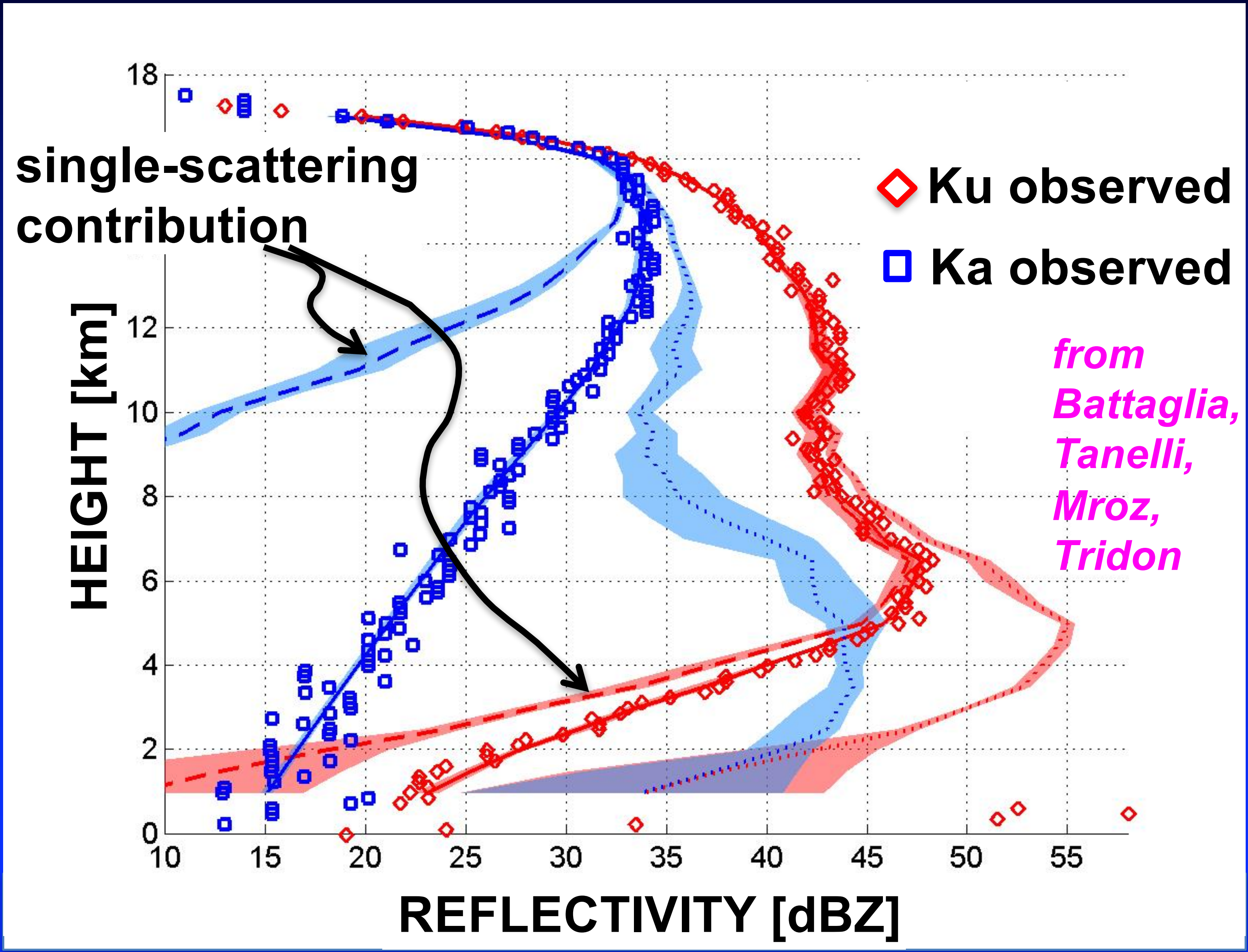



"Downscaling" to Represent Non-Uniform Beamfilling
Uniform Beamfilling
alt.
observed Ku reflectivity profile
Z_{Ku}
estimate
alt.
estimated precipitation profile
LWC
simulate
alt.
simulated Ka reflectivity profile
Z_{Ka}
"downscale"
Non-Uniform Filling
aggregate
aggregate
alt.
$Z_{Ku\ i} = f_i\ Z_{Ku}$
$Z_{Ku\ i}$
estimate
alt.
LWC_i
simulate
alt.
$Z_{Ka\ i}$

Impact of Multiple Scattering

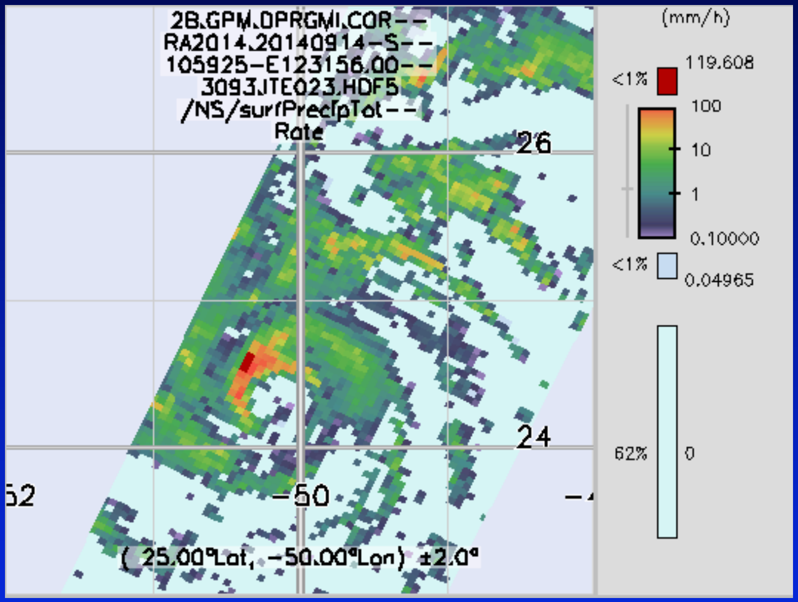


Observed and Modeled DPR Reflectivities

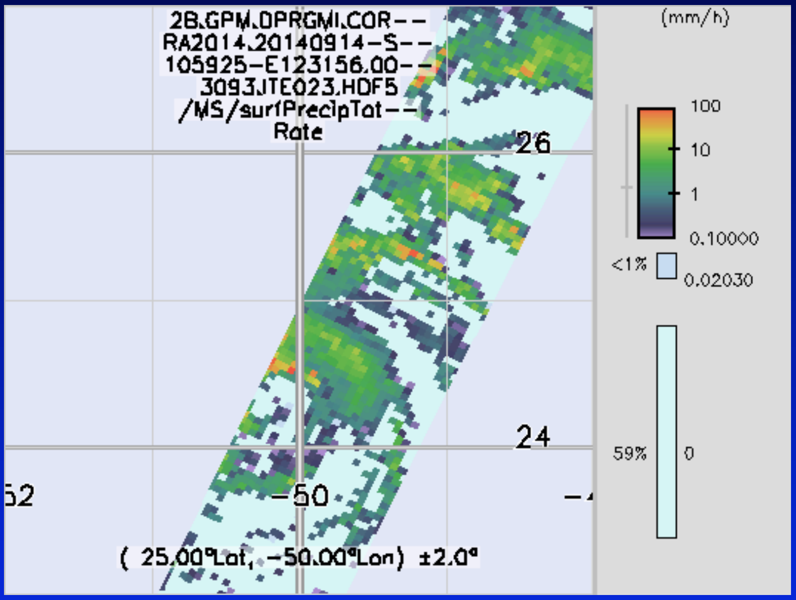


Precip. Estimates from Hurricane Edouard

Ku+GMI Rain Rate

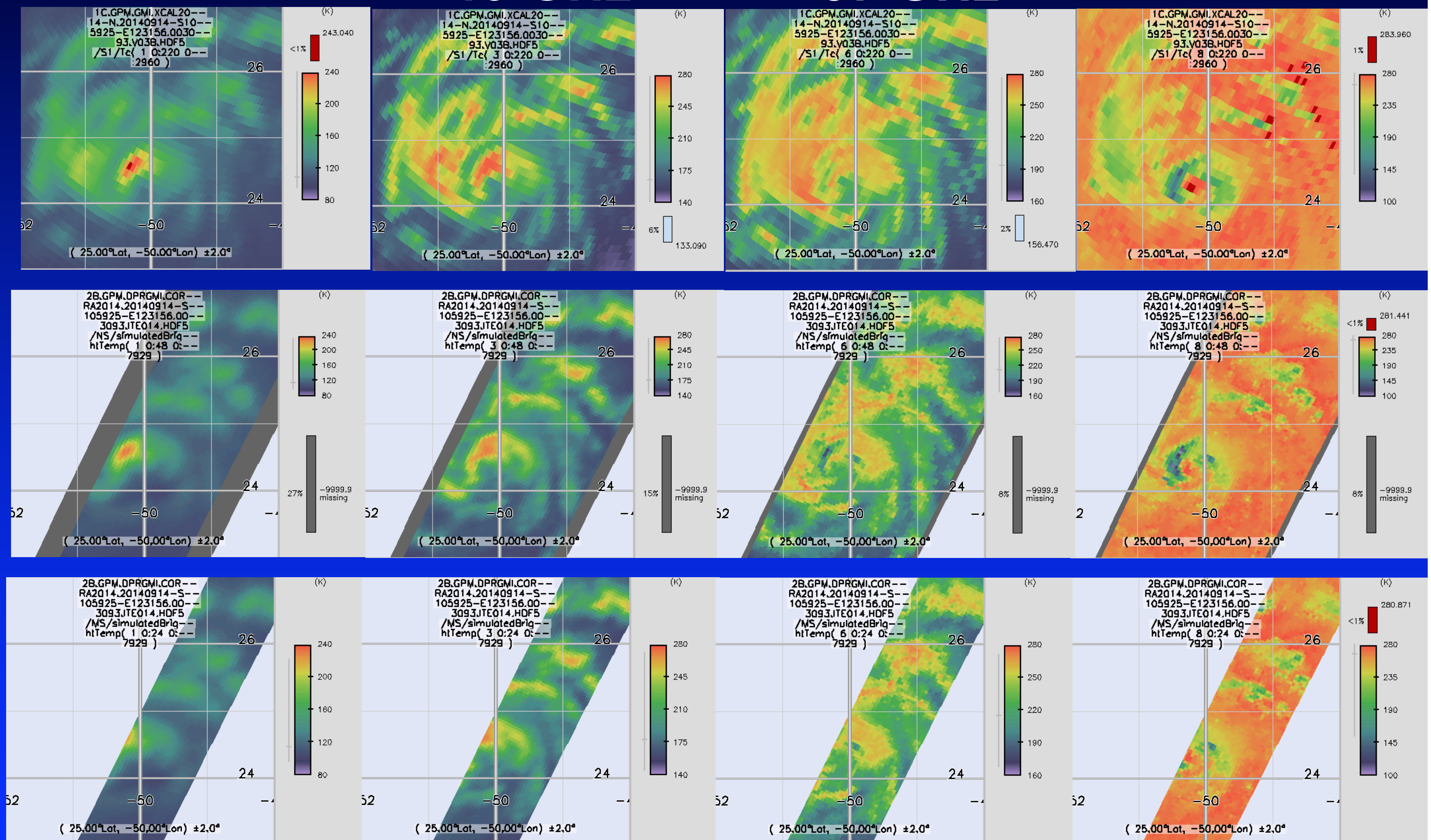


Ku+Ka+GMI Rain Rate



TB Simulations from Hurricane Edouard

	10 GHz	19 GHz	37 GHz	89 GHz
Obs.				
Ku+ GMI est.				
Ku+ Ka+ GMI est.				



Algorithm Theoretical Basis

Generalized Hitschfeld-Bordan Method (applied to Ku-band data only)

- original Hitschfeld-Bordan fast, but reqs. $k = \alpha Z^{\beta}$.

$$Z(r) = \frac{Z_{Ku}(r)}{\left[1 - q\int_0^r \alpha(s) Z_{Ku}^{\beta}(s)\, ds\right]^{1/\beta}}, \quad q \equiv 0.2\,\beta \ln(10)$$

- iterative techniques typically slow.

- alternative interative procedure, assuming $N_o(r)$ and approximate *approximate* β *from k-Z* relation:

$$Z(r) = \frac{Z_{Ku}(r)}{\left[1 - q\int_0^r Z_{Ku}^{\beta}(s)\frac{k(Z(s))}{Z^{\beta}(s)}\, ds\right]^{1/\beta}}$$

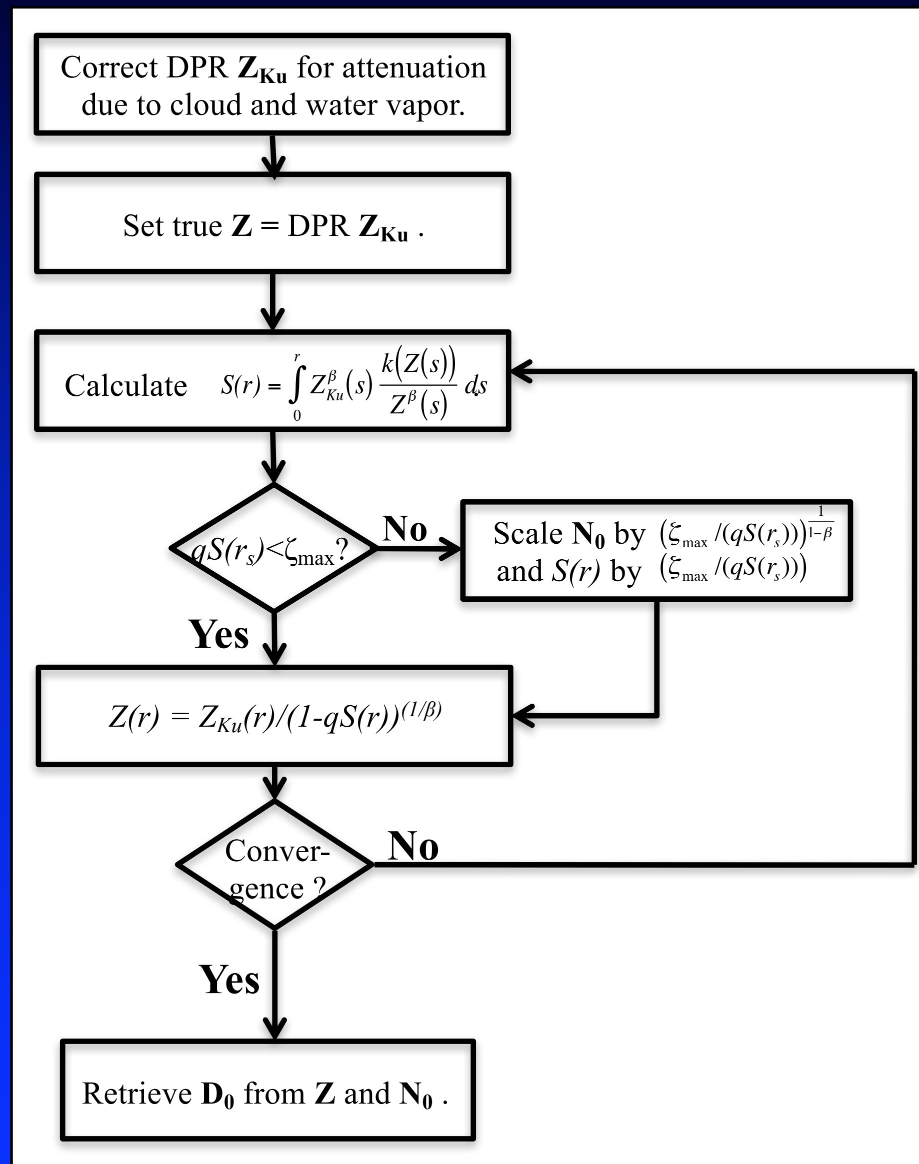
Algorithm Theoretical Basis

Generalized Hitschfeld-Bordan Method

- procedure is fast because iterative equation is a close approx. to H-B solution.

- note procedure avoids instability by rescaling $N_o(r)$, if needed.

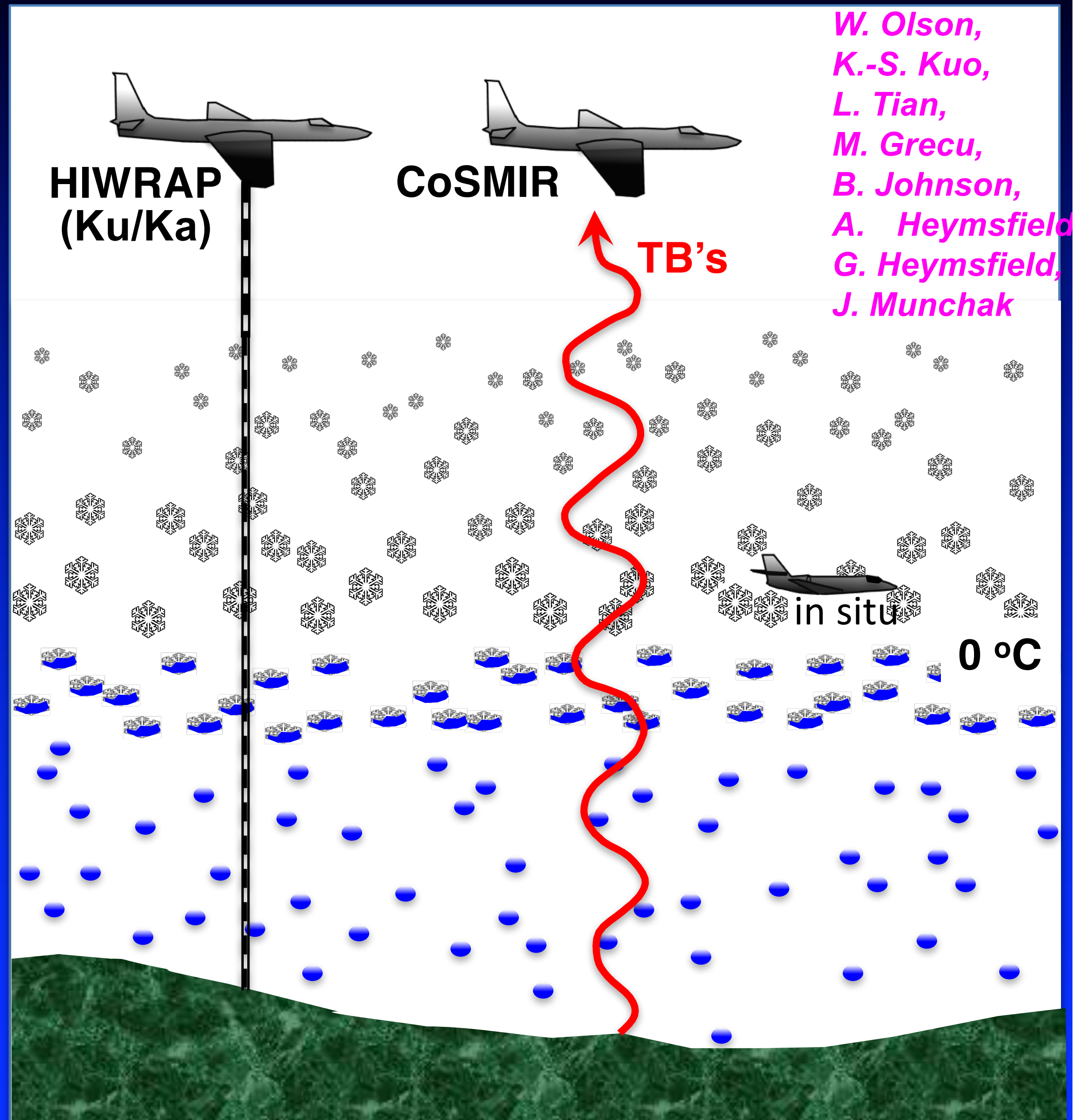
- yields $D_o(r)$, given $N_o(r)$, μ, and Z_{Ku} .



Evaluating Snow Physics Using HIWRAP and CoSMIR in MC3E

- Assign scattering model.
- Retrieve precip profile (PSD's) using HIWRAP.
- Compute consistent microwave scattering properties in profile.
- Simulate upwelling brightness temperatures at 89, 165.5 GHz.
- Compare to CoSMIR obs.

Note: brightness temps aren't sensitive to variations of surface emission and liquid precip if light rain is present => scattering signatures discriminate snow particle models.



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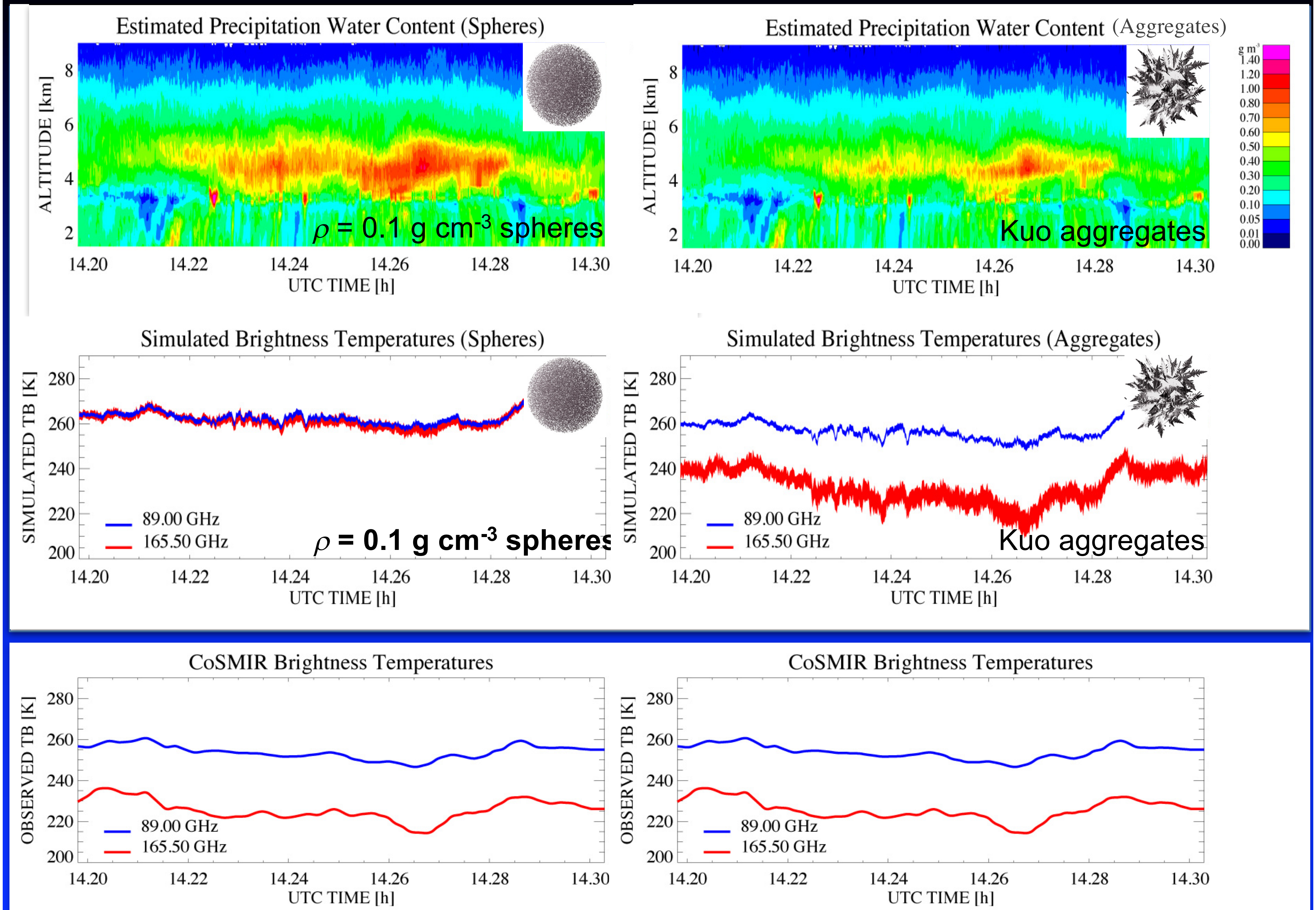
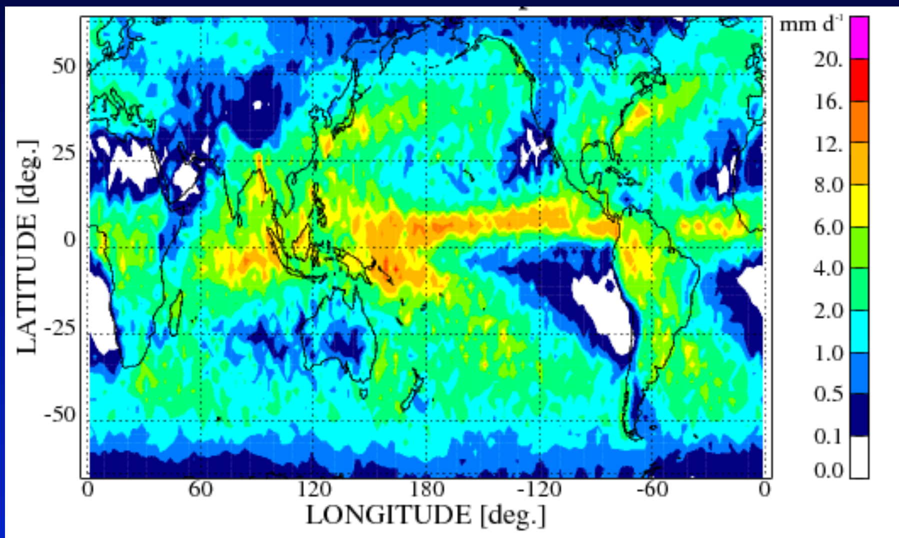
B. Johnson,
A. Heymsfield
G. Heymsfield,
J. Munchak

Radar Retrieval and Simulation of TB's Using Spherical/Aggregate Ice

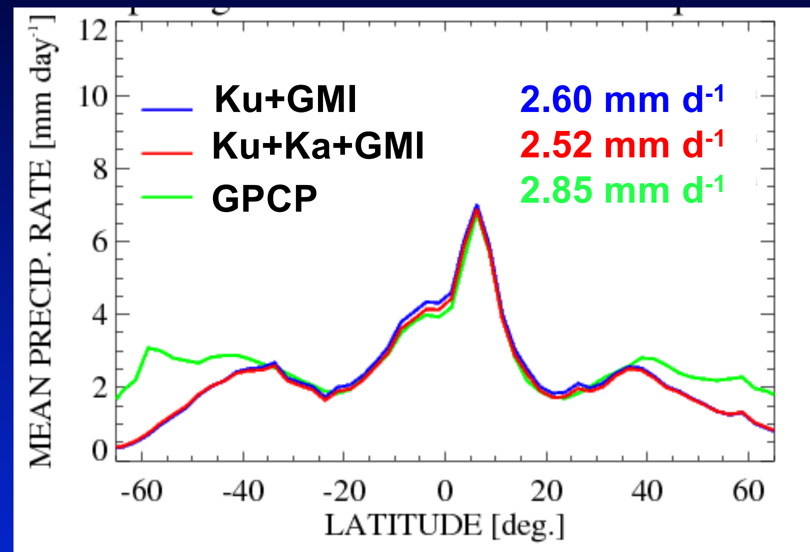


Comparison of GPM Mean Precip. vs. GPCP and MRMS Sep. – Aug. 2014/2015 *Dave Bolvin*

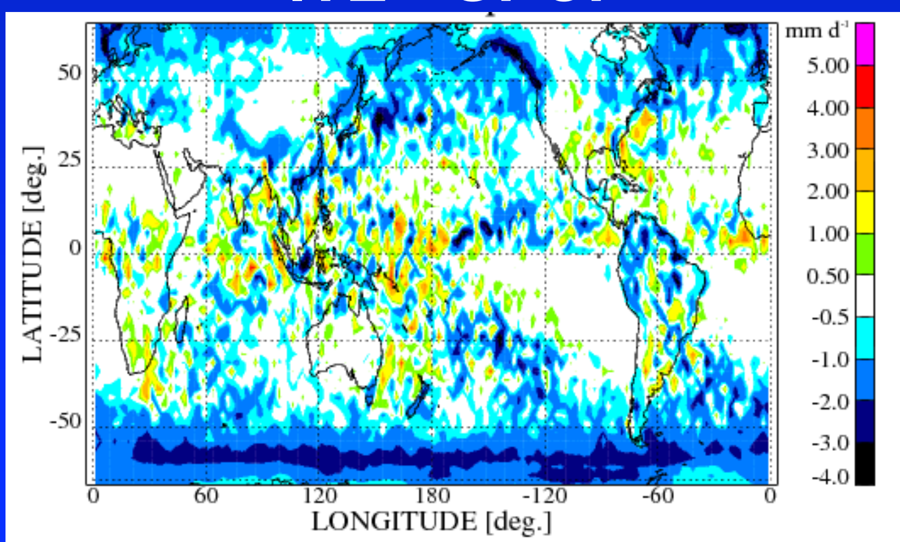
Combined ITE Ku+Ka+GMI



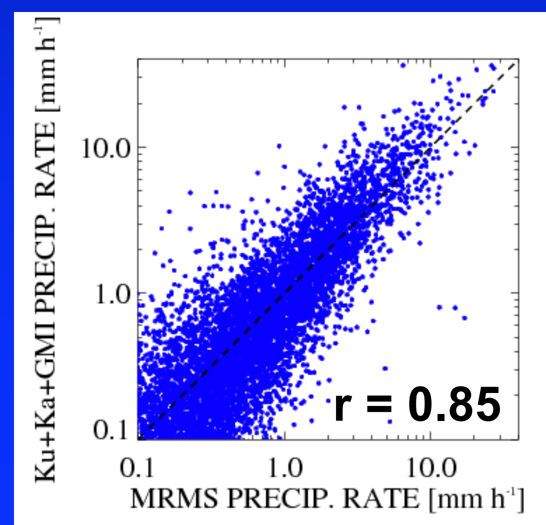
Combined ITE and GPCP



ITE - GPCP

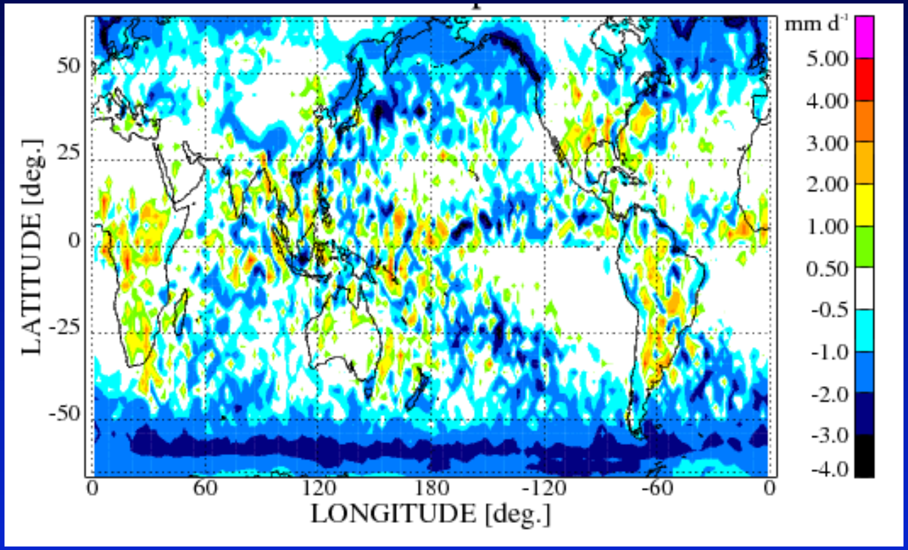


Combined ITE vs MRMS

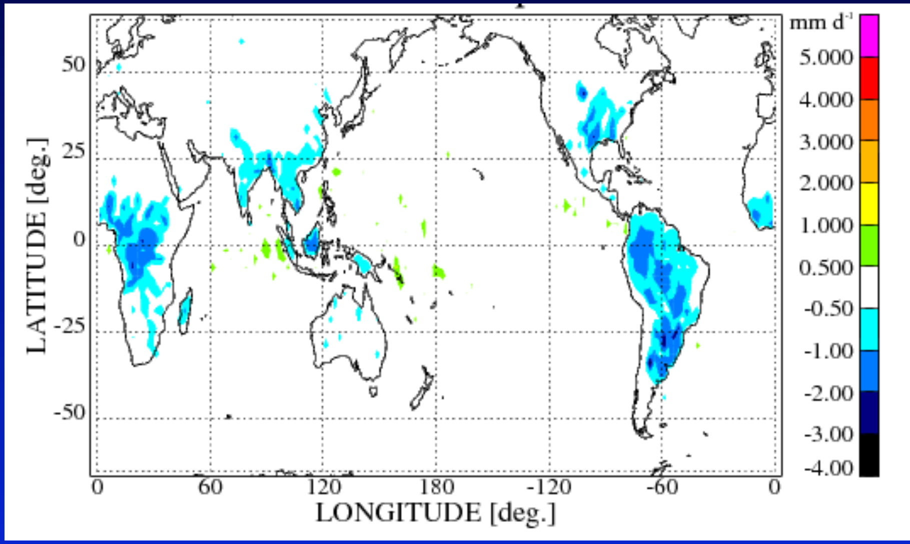


Comparison of GPM V4 vs. ITE
Sep. - Aug. 2014/2015

Combined V4 - GPCP



Combined ITE - V4



Issues with V04:

- estimates over land, particularly in climatologically convective regions, were overestimated.

- overestimation was made even greater by the DPR calibration change.